SEE INSIDE THE FIRST JET FIGHTERS

HOW IT WORKS

EVOLUTION OF THE SOLAR SYSTEM'S **BIGGEST MOUNTAIN**

Turning cow poop into vanilla

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FUTURE
ISSUE 173

SCIENCE TECH ENVIRONMENT SPACE HISTORY TRANSPORT

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WELCOME

Issue 173

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Weird science
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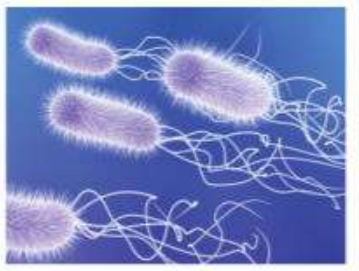
Since 1991, the Ig Nobel Prize has handed out awards for achievements in science and literature that "first make people laugh, and then make them think". Nominees for its debut ceremony included the medicine prize for the inventor of anti-gas liquids that prevent bloating and embarrassment, the biology prize for the man who developed a sperm bank exclusively for Nobelians and Olympians and the peace prize for the father of the hydrogen bomb for his efforts in changing the meaning of peace. You can discover more of these often ludicrously tongue-in-cheek experiments in this issue, and learn how some of them aren't quite as frivolous as they first seem. Enjoy!

Ben Biggs
EDITOR

HIGHLIGHTS



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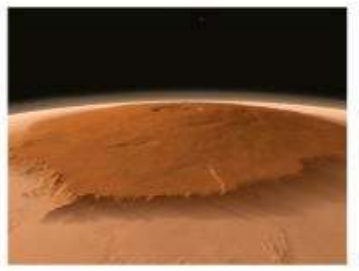

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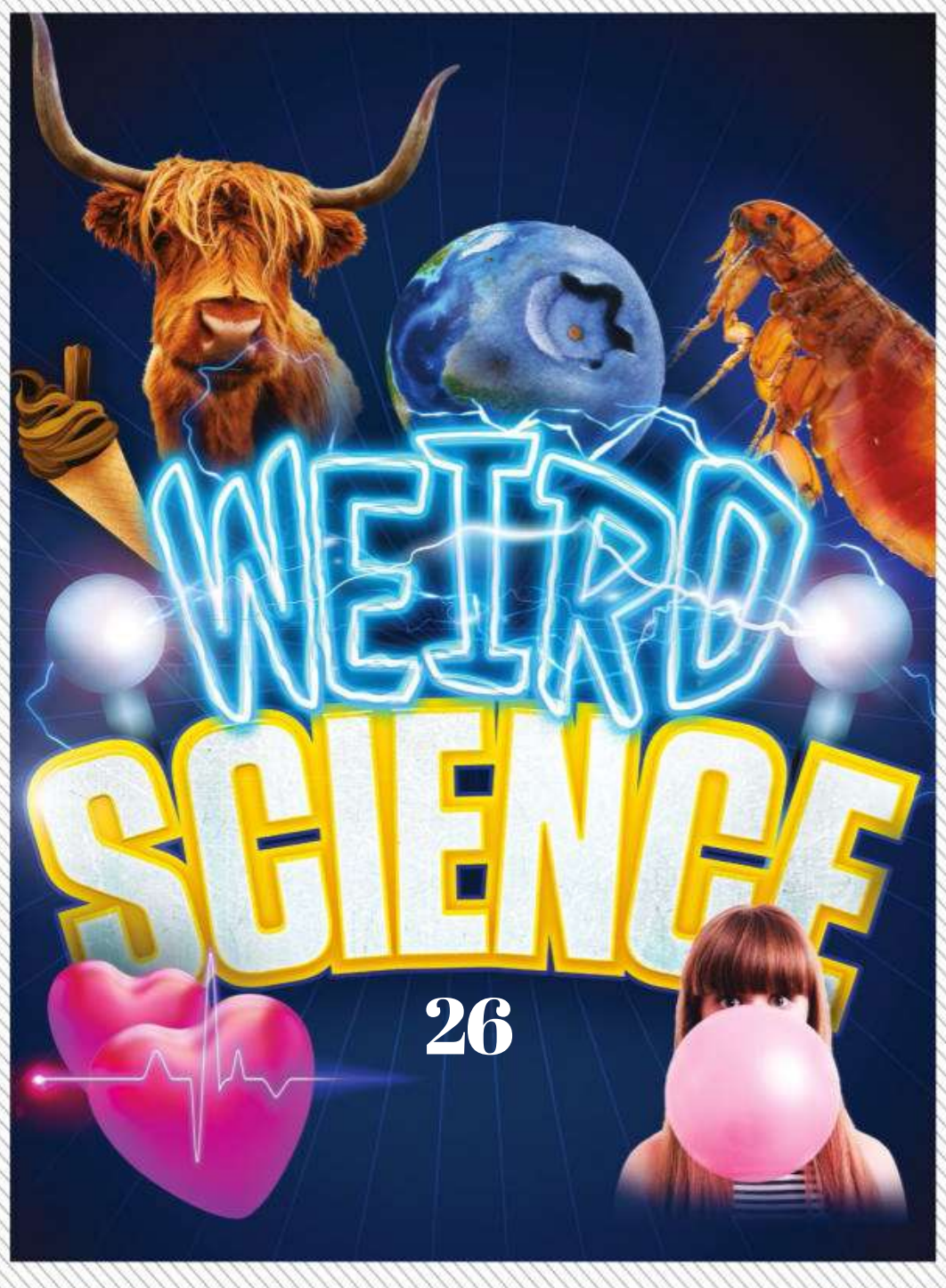

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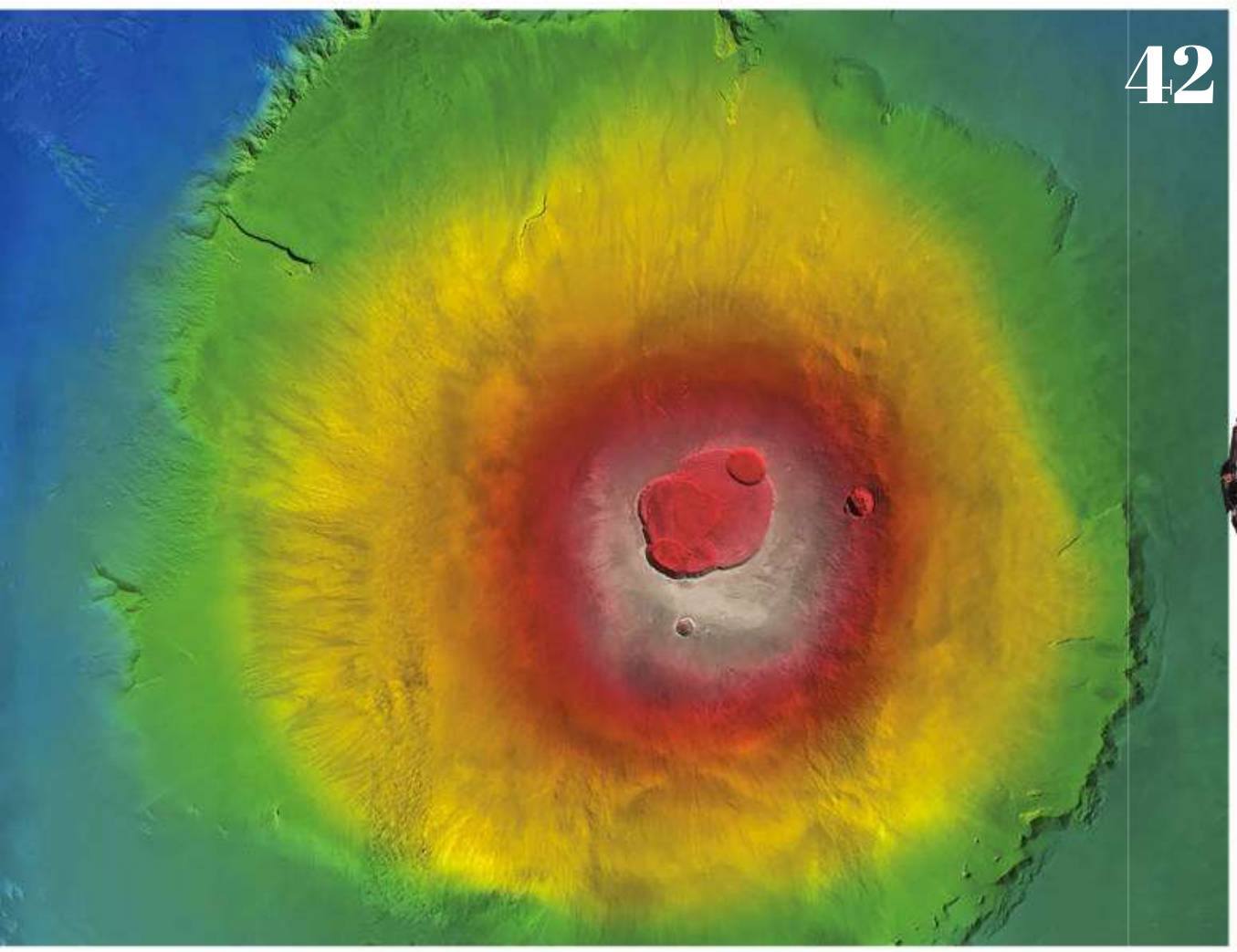

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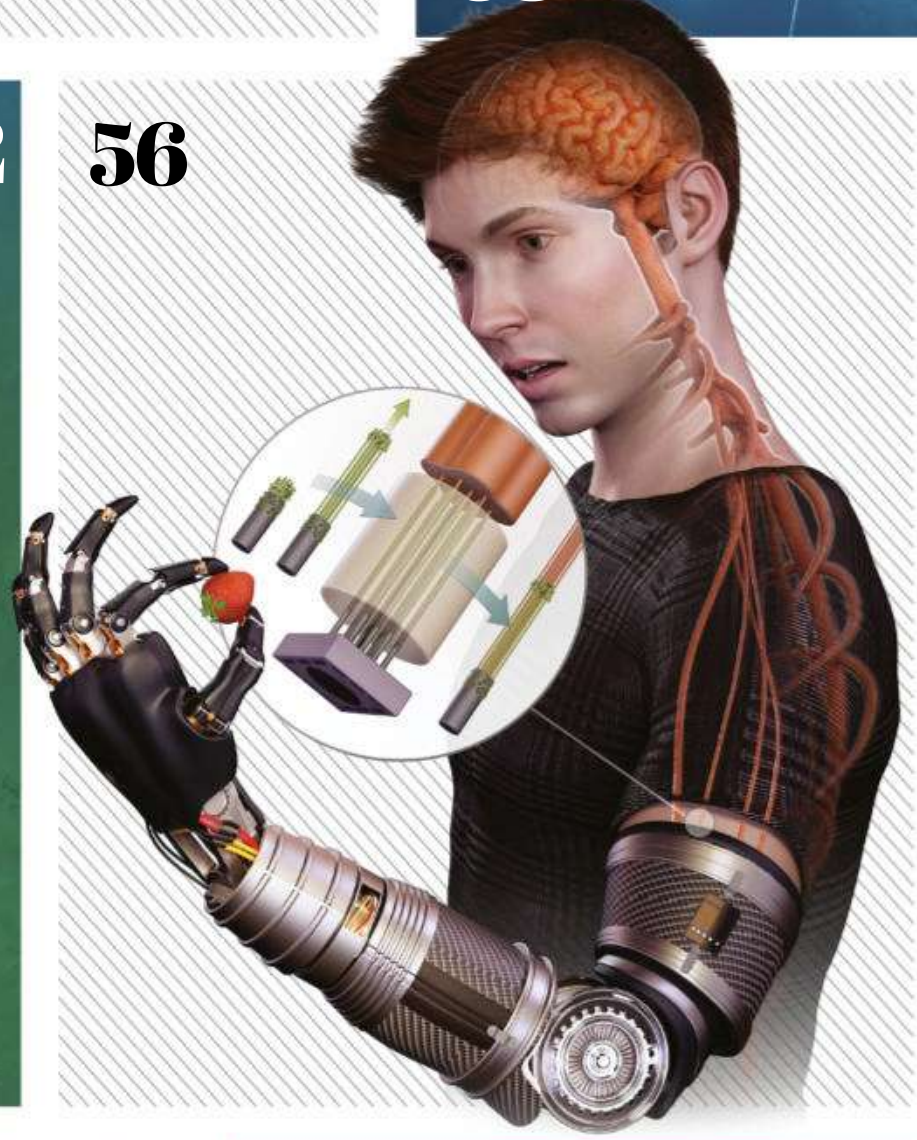

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Stigma under the microscope

These are the reproductive organs of the thale cress flower (*Arabidopsis thaliana*) under confocal microscopy. At the centre of the image is the stigma, the site at which pollen germinates, seen as small green spheres. The short tubular structures are known as the plant's stigmatic papillae – these are designed to trap grains of pollen.

© Getty

Serpent's snack

It's lunchtime for this golden tree snake (*Chrysopelea ornata*), and a blue crested lizard (*Calotes mystaceus*) is on the menu. These venomous snakes are found slithering through the forests of Thailand. To move through the forest canopy, tree snakes can flatten their bodies to glide from branches in search of food. Common snacks are tree-dwelling lizards, rodents, small birds and bats.

© Alamy

Where desert and sea meet

This is Adair Bay, or Bahia Adair, where the Gulf of California meets the Gran Desierto de Altar in northwestern Mexico. Between the arid desert and the waters of the Sea of Cortez are luscious green wetlands of saltwater mangroves, trees and shrubs. The greyish border of the desert is vast salt and mud flats created by evaporating saltwater during low tides.

© NASA/JSC

Cosmic clouds

Hubble snapped this dense cloud of cosmic dust and gas called CB 130-3, around 652 light years from Earth in the constellation of Serpens. CB 130-3 has a dense core made up of compacted dust and gas – the birthplace of stars. When the cores of dense clouds such as this collapse, the pressures and temperatures they generate are enough to ignite the nuclear fusion of hydrogen as a star begins to form.

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GLOBAL EYE

Showcasing the incredible world we live in

Permafrost melts into the Kolyma river outside of Zyryanka, Russia, in Siberia on 4 July 2019

HEALTH

‘Zombie’ viruses revived from Siberian permafrost

WORDS **JOANNA THOMPSON**

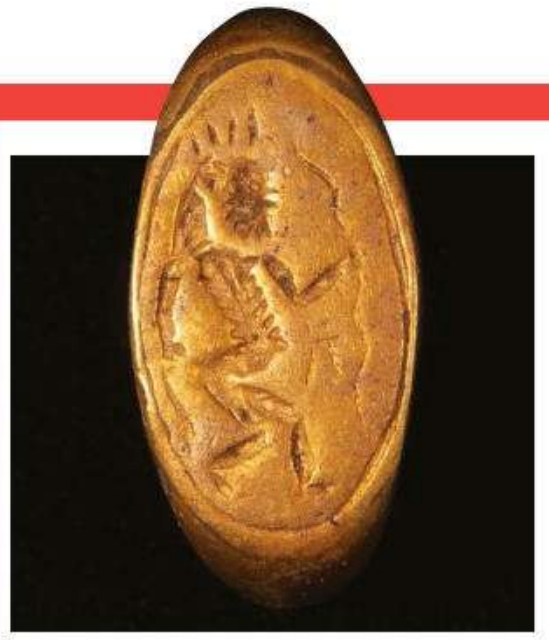
There’s a frozen soup of viruses, bacteria and fungal spores lurking beneath the frigid Arctic soil. Unlike the icy leftovers in the back of your freezer, some of these microbes haven’t interacted with a cell since well before ancient Egyptians built the Pyramids of Giza. As climate change continues to cook the planet, however, these permafrost-locked germs are beginning to thaw. But can newly defrosted microbes ‘wake up’ and infect anything? And how much of a potential threat do they pose to human and environmental health? Those are the questions an international team of scientists began to probe in a recent study.

The researchers isolated 13 newly described viruses from seven permafrost samples and two water samples taken from Siberian rivers. Three of the viruses, named Megavirus mammoth, Pithovirus mammoth and Pandoravirus mammoth, were found inside 27,000-year-old petrified mammoth wool. Another was discovered in the frozen intestines of an ancient Siberian wolf. In a contained lab setting, the scientists carefully thawed the microbes and sequenced their genomes. Then the researchers infected amoeba cells with the newly awakened viruses. Despite being up to 48,000 years old, several of the viruses were able to replicate within the amoebae, causing them to burst open and release fresh viral particles.

“The ones we revived are no danger at all; they only infect amoebae,” said Jean-Michel Claverie, a computational microbiologist at Aix-Marseille University in France, “But their presence and infectivity suggests that ancient viruses infecting animals or humans could still be infectious.” The researchers focused on amoeba-infecting viruses because amoebae make good model organisms and because there would be minimal risk of accidental spillover to lab technicians. “We are using [the amoeba’s] billion years of evolutionary distance with humans and other mammals as the best possible protection,” they said.

Previous studies of viruses locked within Arctic permafrost have been few and far between. However, this study disproves an older hypothesis that permafrost contains few viable microbes; in addition to the viruses they revived, the team found trace evidence of numerous other species, including some related to known human pathogens such as poxviruses and herpesviruses. But if one of these strains did awaken and infect humans, modern vaccines would be likely to offer some protection.

As of now, political upheaval in the region has halted the collection of new permafrost samples. “Because of the Russia-Ukraine war, all our collaborations are stopped now,” Claverie explained, adding that his lab will continue to study the viruses they have. And they hope that companies setting up drilling and mining operations on the Siberian permafrost take heed and proceed with caution, for example by monitoring for unusual diseases and setting up appropriate quarantine facilities. “We believe the point is made that viruses of any kind can survive in permafrost.”



This gold ring shows an engraving of Bes

HISTORY

EGYPTIAN RING FEATURING THE 'GOD OF FUN' DISCOVERED

WORDS **OWEN JARUS**

Archaeologists in Egypt have unearthed stunning gold jewellery, including a ring depicting the 'god of fun', in a burial that's more than 3,300 years old, the Egyptian Ministry of Tourism and Antiquities announced. The burial is located in the northern part of the ancient city of Akhetaten, modern-day Amarna, about 186 miles south of Cairo. This city was built by the pharaoh Akhenaten, who tried to change Egypt's polytheistic religion by focusing it around the worship of the Aten, the sun disc. He moved Egypt's capital city from Thebes in modern-day Luxor to the newly built desert city of Akhetaten. Ultimately, Akhenaten's religious reforms were undone by his son, Tutankhamun, and the new city was abandoned not long after Akhenaten's death.

The recently discovered jewellery includes three rings. One of them has an engraved image of Bes, who was known as 'the god of fun'. Ancient images of Bes are often found in Egypt; the deity is depicted as a dwarf who, in addition to playing music and having fun, also protected women during childbirth, wrote George Hart, who was an Egyptologist at the British Museum. Another ring contains an Egyptian hieroglyphic inscription with the name 'Sat I Plant Tawi', which means 'Lady of the Earth', but it's not clear who this woman is. A gold necklace was also found with the burial.

SPACE

Radioactive space rocks could have seeded life on Earth

WORDS **BEN TURNER**

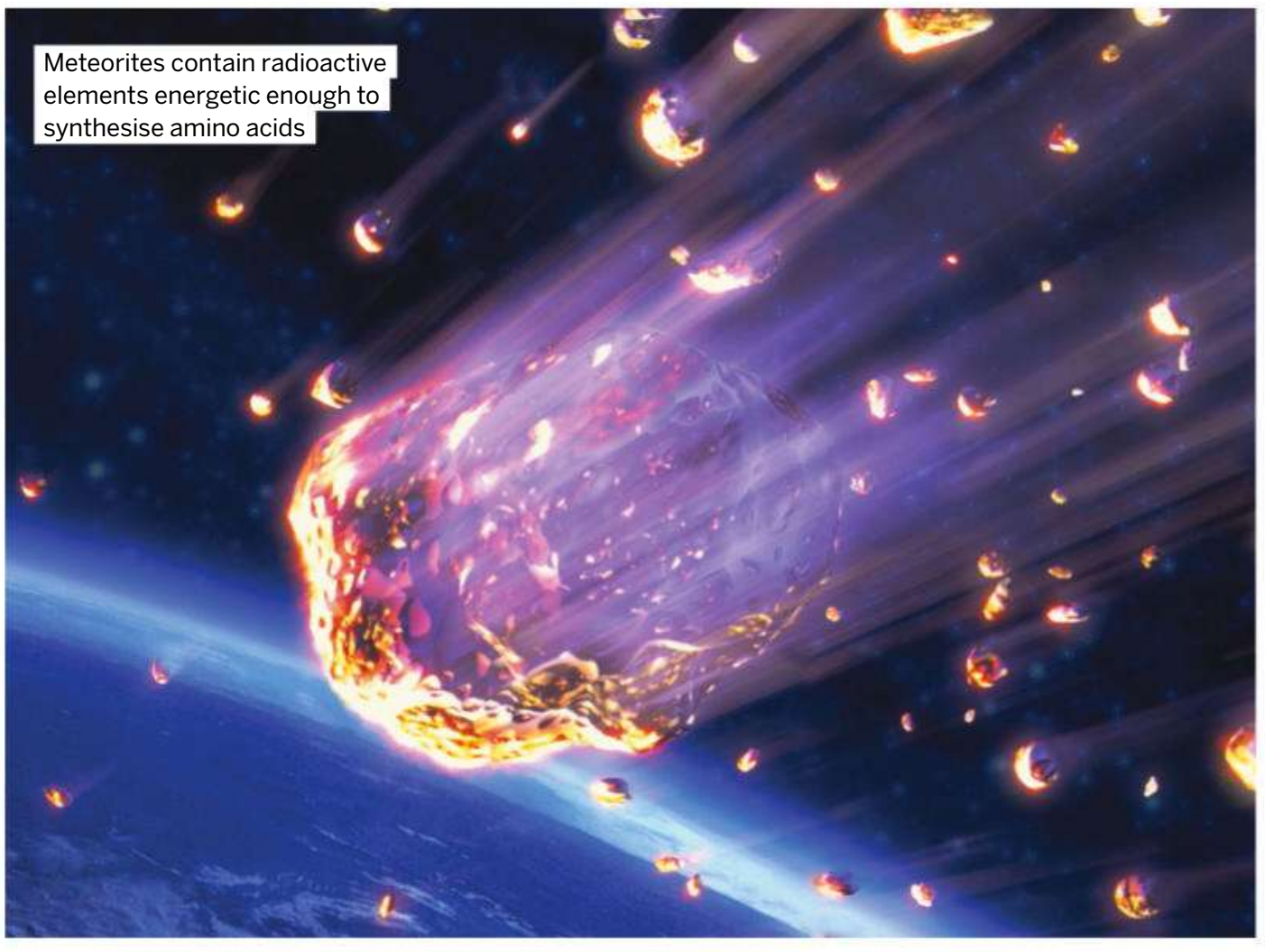
A special type of radioactive meteorite could have seeded life on Earth. Carbonaceous chondrites, a type of radioactive meteorite chock full of water and organic compounds, produce energetic gamma rays that can drive the chemical reactions to synthesise amino acids, the building blocks of life. Meteorites are leftovers from the formation of the young Solar System's rocky inner planets, which first clotted from the hot clouds of gas and dust billowing near the Sun roughly 4.6 billion years ago. At the time, the planets were too close to the Sun to form oceans and so couldn't harbour life, leaving scientists puzzling over how Earth transformed into an oasis of life from its initial barren state. A previous study suggested that water could have been brought to Earth by carbonaceous chondrite meteorites. Now a new study shows that the same meteorites might have brought life's building blocks too.

To see if this was possible, the researchers mixed ammonia, methanol and formaldehyde into water in quantities similar to those found inside meteorites. To see if the radioactive, gamma-ray-producing elements such as aluminium-26 inside the meteorites could generate the heat needed for amino acid synthesis, the researchers irradiated their mixture with gamma rays from an analogue isotope called cobalt-60. Sure enough, the scientists found that the gamma-ray bombardment caused a spike in the production of amino acids inside the solution. Higher gamma-ray production increased the rate of amino acid synthesis. Additionally, the researchers discovered that the proportions of lab-produced amino acids matched those found in the Murchison meteorite, a 100-kilogram space rock that landed in Australia in 1969. Further analysis revealed that it would have taken anywhere from 1,000 to 100,000 years to produce the amino acid quantities found inside the Murchison meteorite.

Did you know?

A meteor that reaches the ground is called a meteorite

Amino acids can be made by many different processes, so while the mechanism the researchers have discovered is a possible candidate for how Earth was seeded by amino acids, it's not the only one. Future research will need to compare this mechanism with others to establish which one likely predominated during Earth's earliest years.



Meteorites contain radioactive elements energetic enough to synthesise amino acids

© Getty / Courtesy of the Egyptian Ministry of Tourism and Antiquities

The Elgin Marbles on display at the British Museum in London

HISTORY

The Elgin Marbles may finally return to Greece

WORDS **OWEN JARUS**

The British Museum and the Greek government are in talks about returning the Parthenon Marbles, also called the Elgin Marbles, to Greece. The marbles are a series of sculptures that once decorated the exterior of the Parthenon, a temple on the acropolis of Athens that was built between about 447 and 432 BCE and is dedicated to the goddess Athena.

The 2,500-year-old sculptures were brought to Britain in the first decade of the 19th century by Thomas Bruce, the seventh Earl of Elgin and Britain's ambassador to the Ottoman Empire, which at that time included Greece. Bruce received permission from the Ottoman Sultan to investigate the Acropolis, although the Acropolis Museum in Greece disputes that he had permission to remove the Parthenon's sculptures. Bruce shipped the artefacts to London, where they first went on display in 1807 and sold to the British government in 1816. Today they are in the Duveen Gallery in the British Museum in London. Not all the sculptures were taken, and some are still in Greece today. Greece has been requesting the return of the marbles for decades, and made a formal request for the Parthenon sculptures' permanent return to Greece in 1983.

Talks between the British Museum and the Greek officials started in November 2021, but a major problem in returning the Parthenon Marbles is that British law stipulates that artefacts in the British Museum cannot be deaccessioned, a process necessary in order to transfer full ownership. The UK government has indicated that it has no plans to change the law, and the two sides are exploring alternatives that might be allowed under British law, such as an agreement that would enable the museum and Greece to share the sculptures. If a deal does come about, a series of exhibitions featuring Greek artefacts that have never left Greece may come to the British Museum, taking up residence in place of the Parthenon Marbles. In Greece, the Acropolis Museum is ready to house the Parthenon Marbles. Currently, plaster casts of the marbles, alongside ancient artefacts the Earl of Elgin left behind, are on display for the public.

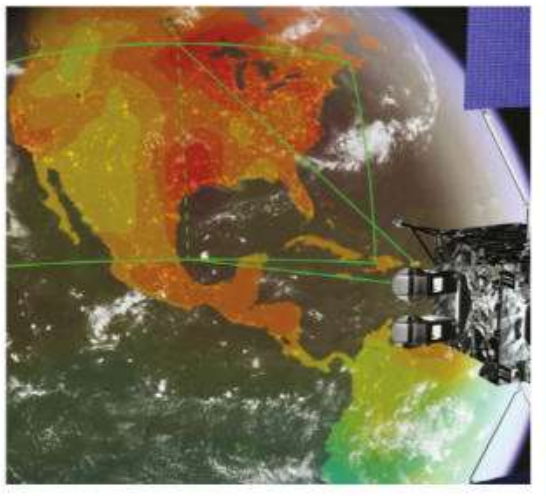
SPACE

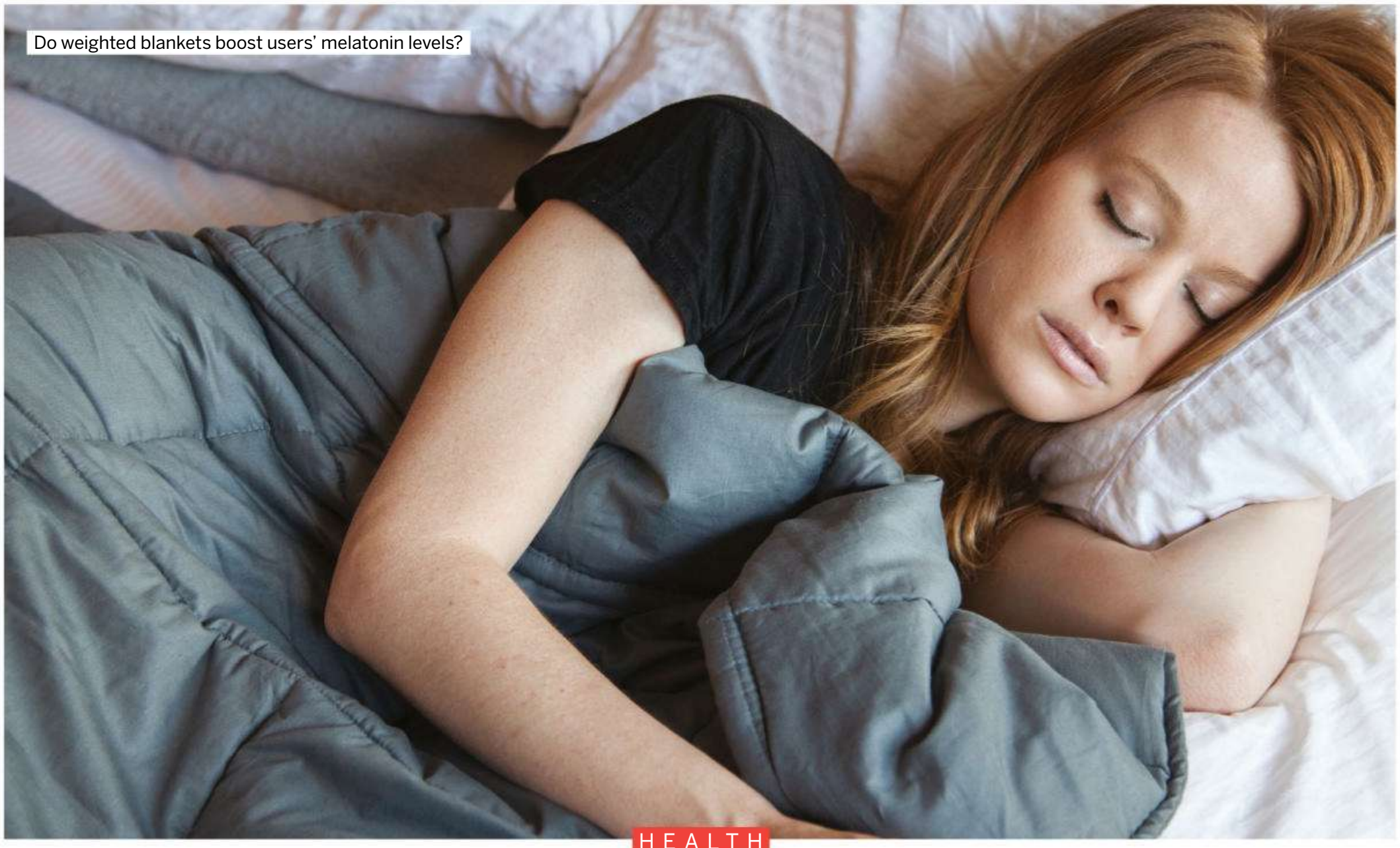
NASA cancels greenhouse-gas satellite

WORDS **STEFANIE WALDEK**

In the case of NASA's GeoCarb mission, some good things must end before they really begin. NASA has cancelled the Geostationary Carbon Cycle Observatory (GeoCarb), a collaboration with the University of Oklahoma and Lockheed Martin that intended to put a greenhouse gas–monitoring satellite into geostationary orbit. GeoCarb would have measured levels of carbon dioxide, carbon monoxide and methane in the atmosphere about 4 million times per day. The mission was selected by NASA in 2016. "Decisions like this are difficult, but NASA is dedicated to making careful choices," said Thomas Zurbuchen, NASA's associate administrator for science. "We look forward to accomplishing our commitment to state-of-the-art climate observation in a more efficient and cost-effective way."

The decision to end GeoCarb was due to "technical concerns, cost performance and availability of new alternative data sources." The most recent anticipated cost of GeoCarb was $600 million (£494 million). As for those new data sources, they include the new Earth Surface Mineral Dust Source Investigation (EMIT) instrument that arrived at the International Space Station (ISS) in July, as well as the mission extension of the Orbiting Carbon Observatory-3 instrument that began work in 2019.


An artist's representation of GeoCarb studying carbon gases above Earth



HEALTH

A weighted blanket may boost the sleep hormone melatonin

WORDS **NICOLETTA LANESE**

Using a weighted blanket at bedtime may boost the body's production of the sleep-promoting hormone melatonin. At this point, it's unclear why the hefty blankets might increase melatonin levels and whether this significantly improves people's sleep quality. "This is a very interesting study, but it would be nice to see it replicated in a second cohort because it's not an obvious thing that melatonin should increase with a weighted blanket," said Håkan Olausson, a neuroscientist at Linköping University in Sweden.

Melatonin helps the body transition into sleep mode, during which body temperature falls, metabolism slows and levels of the stress hormone cortisol decrease; melatonin also increases drowsiness in the hours before bed. Melatonin levels generally increase in the evening, peak at night and decrease as morning approaches. That's because part of the brain called the suprachiasmatic nucleus (SCN) syncs melatonin production with the time of day. The SCN does so by monitoring light-related signals from the retina. Bright light prompts the SCN to shoot electrical signals to other brain structures, which then relay the message through the spinal cord and on to organs. This chain message eventually reaches the pea-size pineal gland, which pauses its production of melatonin. Conversely, dim light and darkness lift the brakes on the pineal gland and jump-start melatonin production. In addition to light, environmental factors such as the timing of meals, physical activity and social interactions can sway somewhat when melatonin gets made.

Scientists wondered whether a different sensory cue, the pressure of a weighted blanket, might also influence melatonin production. To investigate, they asked 11 women and 15 men in their 20s to spend a few nights sleeping in a lab, once to get used to the environment, once under a lightweight blanket and once under a weighted blanket. None of the study participants had insomnia or had previously used weighted blankets. During a session, each participant would eat dinner, sit in bright light for two hours and then sit in dim light until lights out at 23:00. One hour before lights out, they would snuggle up under either the lightweight or weighted blanket. In that hour, the researchers took saliva samples every 20 minutes to monitor each subject's melatonin levels.

On average, when under a weighted blanket, the participants' melatonin levels rose about 32 per cent higher than they did under the lightweight blanket, although the study can't show why this was. What's more, using the blanket did not seem to affect the participants' sleep; they were just as sleepy before bedtime and after waking up in both scenarios, and their total sleep time was the same in both scenarios. "Future studies should investigate whether the stimulatory effect on melatonin secretion is observed on a nightly basis when frequently using a weighted blanket over weeks to months," the researchers wrote. "It remains to be determined whether the observed increase in melatonin may be therapeutically relevant for the previously described effects of the weighted blanket on insomnia and anxiety." It's also not clear whether the observed melatonin boost would be seen in other groups, including older people, given that people's circadian rhythms often become disrupted with age.

Did you know?

Around 15 per cent of people sleepwalk

© Getty / University of Oklahoma

STRANGE NEWS

THE US MILITARY REPORTS 'SEVERAL HUNDRED' UFO SIGHTINGS

WORDS **BRANDON SPECKTOR**

The US government's new UFO-tracking office has been open for half a year, but business is booming. Over the last six months, the All-Domain Anomaly Resolution Office (AARO) has received 'several hundred' new UFO reports from US military personnel. This adds to more than 140 UFO sightings reported by the military between 2004 and 2021. The new reports, filed this year by personnel in the Army, Navy and Air Force, describe unidentified anomalous phenomena, or UAPs, the government's preferred name for UFOs, sighted in the air, underwater and in space. None of the reports show any hint of alien activity.

AARO's mission is to consolidate and investigate UFO reports filed by branches of the US military. By definition, a UAP is "anything in space, in the air, on land, in the sea or under the sea that can't be identified and which might pose a threat to US military installations or operations," according to the Department of Defense. The sudden influx of new reports may be thanks to recent outreach efforts by AARO.

A number of reported sightings have already been resolved, anonymous Pentagon officials said. Many UFO sightings can likely be attributed to 'relatively ordinary' surveillance drones from nations such as China and Russia, officials said, while others may simply be 'airborne clutter' like weather balloons.

The Pentagon, home to the US Department of Defense, is being flooded with UFO reports

ANIMALS

American black bears evolve cinnamon-coloured coats

WORDS **JENNIFER NALEWICKI**

Some American black bears in the western US have evolved to have cinnamon-coloured fur. The new hue is likely due to a genetic variant similar to one that causes albinism in humans. Researchers from the US and Japan analysed DNA samples from 151 American black bears (*Ursus americanus*) across the US and Canada and found that those residing in western states such as Nevada, Arizona and Idaho were more likely to exhibit reddish coats than the black fur for which the medium-sized bears are named. They identified a mutation known as R153C in a gene called tyrosinase-related protein 1 (TYRP1) that causes an alteration in the coat's pigmentation that makes its fur the same colour as a copper penny. "TYRP1 is a known pigmentation gene that ultimately produces either eumelanin, black or brown pigment, or pheomelanin, red or yellow pigment," Emily Puckett, an assistant professor in biological sciences at the University of Memphis in Tennessee, said. "What it's doing is changing the amino-acid sequence of that gene." This 'cinnamon variant', which Puckett calls "a young mutation," came about approximately 9,360 years ago and has gradually spread through the population.

Black bears elsewhere in the US, including along the Great Lakes and in the Northeast, are less likely to exhibit red-hued fur because this young mutation hasn't had enough time for natural migration. "Geography plays a part," Puckett said. "Our demographic modelling identified that the most likely place where the mutation arose was somewhere in the western region, very likely in the Southwest. From there, it expanded through gene flow throughout populations." But even that is a slow process, with the majority of black bears on the East Coast still sporting jet-black fur. "The bears don't pass through the Great Plains," Puckett said. "If they wanted to go east, they would have to go up north to Canada, across the Canadian Prairies, around the Great Lakes and then drop back down into the eastern populations. That would take a long time. We do see that it's happening and is moving, but it's a process that takes time."

The researchers also examined whether or not the development of this gene in western American black bears had anything to do with thermoregulation, a mechanism that helps mammals regulate their body temperatures, or competition with another cinnamon-coloured bear species, brown bears (*Ursus arctos*), also known as grizzly bears. "Our modelling suggests that yes, [the gene is] adaptive in some way, but we're not 100 per cent sure what it's adapted to," Puckett said. "We tested for both thermoregulation and competition with brown bears, and neither were strongly supported. Our new hypothesis is that it's a mechanism for selective advantage."

Some American black bears have evolved to have a cinnamon-coloured coat

PLANET EARTH

Greenland's glaciers are melting faster than estimated

WORDS STEPHANIE PAPPAS

Greenland's glaciers are melting 100 times faster than previously calculated according to a new model that takes into account the unique interaction between ice and water at the island's fjords. The new mathematical representation of glacial melt factors in the latest observations of how ice gets eaten away from the stark vertical faces at the ends of glaciers in Greenland. Previously, scientists used models developed in Antarctica, where glacial tongues float on top of seawater, a very different arrangement. "For years, people took the melt rate model for Antarctic floating glaciers and applied it to Greenland's vertical glacier fronts," said Kirstin Schulz, a research associate at the Oden Institute for Computational Engineering and Sciences. "But there's more and more evidence that the traditional approach produces too-low melt rates at Greenland's vertical glacier fronts."

Researchers already knew their Antarctica-based understanding of Arctic glaciers wasn't a perfect match. But it's hard to get close to the edges of Greenland's glaciers because they're situated at the ends of fjords. This leads to dramatic calving events where chunks of ice the size of buildings crumble into the water with little warning, creating mini-tsunamis. Led by physical oceanographer Rebecca Jackson of Rutgers University, the team has been using robotic boats to get close to these dangerous ice cliffs and take measurements. They've done this at Alaska's LeConte Glacier, as well as Greenland's Kangerlussuuq Sermia. An upcoming mission led by scientists at the University of Texas at Austin will send robotic subs to the faces of three west Greenland glaciers. Jackson's measurements suggest that the Antarctica-based models massively underestimate Arctic glacial melt. LeConte, for example, is disappearing 100 times faster than models predicted.

The mixture of cold freshwater from the glaciers and warmer seawater drives ocean circulation near the glaciers and farther out in the ocean, meaning the melt has far-reaching implications. The Greenland ice sheet is also important for sea-level rise; Greenland ice holds enough water to raise sea levels by six metres. The new model uses the latest data from near-glacial missions along with a more realistic understanding of how the steep, cliff-like faces of the glaciers impact ice loss. Results are consistent with Jackson's findings, showing 100 times more melt than the old models predicted. "Ocean climate model results are highly relevant to predict trends associated with climate change, so you really want to get them right," Schulz said. "This was a very important step for making climate models better."

Did you know?

Glaciers cover about ten per cent of Earth's surface

In this aerial view, icebergs and meltwater are seen in front of the retreating Russell Glacier on 8 September 2021 near Kangerlussuaq, Greenland

© Getty

Evolution of clouds on Titan over 30 hours between 4 and 6 November 2022

SPACE

Webb captures extraordinary clouds on Titan

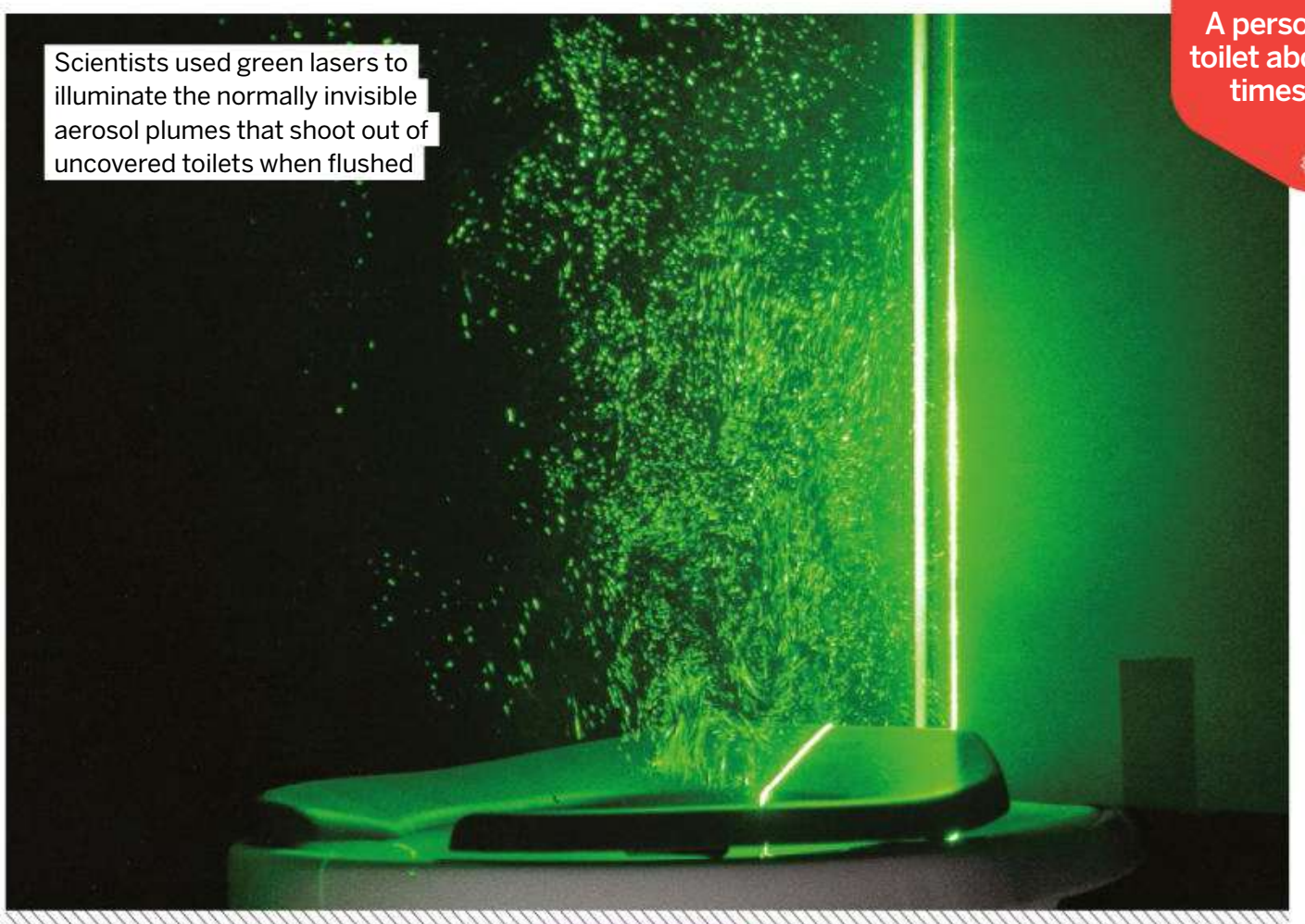
WORDS JOANNA WENDEL

Scientists spotted something exciting on Saturn's moon Titan in images taken by NASA's James Webb Space Telescope in early November: clouds. Specifically, clouds in Titan's northern hemisphere. To a casual observer, clouds might be a dime a dozen. But to scientists, clouds can reveal a lot about the atmosphere of a planet, or in this case, a moon. Titan is the only moon in the Solar System with a thick atmosphere, so studying clouds helps scientists understand how Titan's atmosphere works, and why it has an atmosphere in the first place. The clouds further validate weather models that predict the appearance of clouds in Titan's northern hemisphere during its summer, when the region is bathed in sunlight.

Scientists have eagerly been awaiting observations of Titan since NASA's Cassini mission ended after plunging into Saturn's atmosphere in 2017. Titan's atmosphere is thick with nitrogen and methane, stretching 370 miles into space, an altitude ten times taller than Earth's atmosphere. At its outer edges, solar radiation breaks up the methane and nitrogen molecules, and the remaining pieces recombine into large organic molecules that create a rich, soupy haze. This haze blocks visible light, making it hard to observe Titan's lower atmosphere and surface. Fortunately, Webb's infrared cameras will be able to give scientists an unprecedented view of the moon's lower atmosphere and surface.

Although NASA's Goddard team was excited about seeing clouds, the Webb images showed only one snapshot in time. To really understand how Titan's atmosphere works, researchers need multiple images to see how the clouds change shape. So the team turned to colleagues at an Earth-based telescope, the Keck Observatory in Hawaii. Thankfully, the clouds hadn't dissipated by the time Keck made its observations a couple of days later. "We were concerned that the clouds would be gone when we looked at Titan two days later with Keck, but to our delight there were clouds at the same positions, looking like they had changed in shape," said Imke de Pater, a Dutch planetary scientist at the University of California, Berkeley.

Titan captivates scientists for many reasons. For one, ultraviolet radiation from the Sun creates huge organic molecules in Titan's nitrogen and methane-rich atmosphere. That hazy atmosphere obscures a surface covered in vast fields of dunes, along with lakes, seas and rivers of liquid hydrocarbons like methane and ethane. And deep underneath Titan's surface, scientists suspect a salty liquid water ocean lurks, making Titan a candidate for potential life beyond Earth. The cloud images aren't the only data Webb returned in early November. Using data from the telescope's Near-Infrared Spectrograph, scientists will be able to study the composition of Titan's lower atmosphere, which can't be observed using ground-based telescopes like Keck. That data, which the team is still analysing, "will enable us to really probe the composition of Titan's lower atmosphere and surface in ways that even the Cassini spacecraft could not," the team said.



Scientists used green lasers to illuminate the normally invisible aerosol plumes that shoot out of uncovered toilets when flushed

HEALTH

Uncovered toilets shoot out aerosol plumes

WORDS HARRY BAKER

Unnerving new videos show how gross it can be to flush toilets without a seat cover, particularly when using public bathrooms. The stomach-turning footage shows how aerosol plumes shoot out of toilet bowls like a rocket when they are left uncovered. When a toilet is flushed it doesn't just wash away the solids and liquids that we leave behind; it also ejects a near-invisible cloud of microscopic droplets that in the past have been shown to spread harmful pathogens found in faeces, including bacteria and viruses, that can remain in a toilet bowl even after several flushes.

In a recent study, researchers used vibrant green lasers to illuminate aerosol plumes given off after flushing a lidless toilet, similar to those used in public bathrooms. Once these plumes were illuminated, the team used special high-speed cameras to film how the minuscule droplets moved through the air and track how far they spread. The results were much more alarming than the researchers initially predicted. "If it's something you can't see, it's easy to pretend it doesn't exist," said John Crimaldi, a geoenvironmental engineer at the University of Colorado, Boulder. "But once you see these videos, you're never going to think about a toilet flush the same way again."

Scientists have known for around 60 years that uncovered toilets emit aerosols, and past studies had detected how far the aerosols could potentially reach. But until now, exactly how the plumes formed, how quickly they moved and how long aerosols persisted had remained a mystery. The new videos revealed that these airborne particles shoot out at speeds of two metres per second. This propulsion allows them to reach 1.5 metres above the toilet within eight seconds, which "is a much more energetic and rapidly spreading plume than even the people who knew about this understood," Crimaldi said.

The experiments also highlighted that the size of airborne particles can affect how long they remain suspended in the air. While the largest droplets tended to settle onto surfaces within seconds, the smaller particles, less than five micrometres across, can remain suspended in the air for minutes or longer, the researchers wrote. Pathogens that lurk in faeces include bacteria such as *Escherichia coli* and *Clostridium difficile*, as well as noroviruses and adenoviruses, which can all cause serious stomach and intestinal problems. In 2020, two people who had been hospitalised in France after contracting Legionnaire's disease were likely infected by aerosols given off by a public toilet. At home, people can avoid this problem by putting down the toilet lid before they flush. But in public, where most toilets can't be covered, this isn't so easy.

Did you know?

A person uses a toilet about 2,500 times a year

ANIMALS

JOUSTING ANKYLOSAURS WHACKED THEIR PEERS WITH THEIR TAILS

WORDS JENNIFER NALEWICKI

With massive tails studded with spikes, ankylosaurs were armoured herbivores that could do real damage in a fight. Palaeontologists once thought that these tank-like dinosaurs used their tail clubs solely to fight off predators, but a new study reveals that they also bashed each other in a show of dominance. Researchers examined *Zuul crurivastator*, the most complete fossilised ankylosaur, on display at the Royal Ontario Museum (ROM) in Toronto, Canada.

Measuring six metres and weighing 2,500 kilograms, the 76-million-year-old specimen from the Cretaceous period contains several broken spikes along its flanks. Sections of fossilised skin on its flanks also show that *Zuul*'s side wounds healed while the dinosaur was still alive. "The fossilised skin preservation over the damaged bony plates blew me away. Seeing the healing reflected in the soft tissue is something really special about *Zuul*," said David Evans of ROM. "*Zuul* gives us a remarkable picture of what these animals looked like when they were alive." For years, scientists believed that ankylosaurs only used their 'sledgehammer-like' tails to swat away predators. This is true. However, the injuries inflicted on *Zuul* add another piece to the puzzle.

Artist's interpretation of an ankylosaurus walking through a swamp

© Getty / University of Colorado Boulder / NSAS, ESA, CSA, Webb

WISH LIST

The latest tech for STEAM TOYS

LIGHT-UP TERRARIUM KIT FOR KIDS

DANANDDARCI.COM £24.99 / $24.99

A terrarium is a self-contained miniature garden within a transparent vessel, like a large glass jar, that simulates a natural environment. Once set up in a suitably lit location and sealed, a terrarium has everything it needs to sustain itself – no watering or feeding necessary. A well-made terrarium can last years without unsealing it. With the Light-Up Terrarium Kit for Kids, you can create your own customised mini garden in a jar that will glow at night. Let your child discover the beauty of nature with this all-inclusive kit and watch as it grows each day. Beneath the lid there's a built-in innovative LED light that transforms the experience into something magical. At night, just hit the small switch to turn on the light and watch how your terrarium turns into a gorgeous illuminated tabletop garden. The light can easily be recharged with the included Micro-USB cable and the kit includes a terrarium jar, vermiculite soil, wheatgrass and chia seeds.

FLASHDASH 4-IN-1 ELECTRONIC GAME FOR KIDS AND ADULTS

WINNINGFINGERS.COM £34.99 / $39.99

Flashdash offers four quick-fingered games in a unique light-up cube design. Great for home and travel, these fun handheld games help improve brain skills and hand-eye coordination. It includes a simple speed game called 'Chase Me', as well as popular classics like 'Simon Says'. They're easy to learn, but tough to master. This electronic games cube offers just the right amount of challenge for most people. When you're done playing, you can press the light show button to enjoy a fun display of flashing lights.

MBOT SMART STEM EDUCATIONAL CODING ROBOTIC KIT

STORE.MAKEBLOCK.COM £109.99 / $89.99

The mBot is a DIY robotics kit that lets children discover the secrets of programming, robotics and electronics in a single easy-to-use yet expansive package. It's designed for learning these STEAM subjects in a simple and fun way, with interactive software and rich tutorials via the online community and the included coding cards. Matched with three free Makeblock apps and software, kids can enjoy remote controlling the mBot and playing programming games, as well as programming mBot directly. The mBot is configured with an open-source system, so it's compatible with a large number of add-on packs that can be contributed by the programming community, connecting to 100-plus electronic modules and 500-plus parts from the Makeblock platform. It's an ideal learning and educational gift for youngsters.

LIGHT-UP CRYSTAL GROWING KIT FOR KIDS

DANANDDARCI.COM
£24.99 / $29.99

Grow your own crystals and make them glow with the Light-Up Crystal Growing Kit for Kids. Let your child feel like a real chemist in this simple process: mix the special ingredients in water, then watch the crystals grow day by day as they follow along with the beautifully illustrated 12-page booklet describing how crystals are formed. When they're done and a fully grown crystal has appeared out of the solution, they can turn their newly formed crystals into a piece of art by placing them on the included LED Light-up Display, watching as the lights burst through the complex crystal formations. This kit includes everything needed for the young scientist to grow the crystals with ease and gain a deeper understanding of them.

SNAP CIRCUITS ARCADE

SHOP.ELENCO.COM £69.99 / $83.99

Get to grips with the basics of electricity with a value-packed build-your-own arcade board that features 30 snap modules with a staggering 200 projects in just one device. Snap Circuits Arcade is a great introduction for budding engineers and DIY enthusiasts to following instructions, problem-solving and the all-important satisfaction of a job well done at the end of the project. You can build over 20 games with sounds and lights with this 36-piece kit. It uses building pieces with snaps to assemble different electronic circuits on a simple 'rows and columns' base grid that functions like the printed circuit boards found in most electronic products. Enjoy completing projects using a programmable word fan, dual LED display and a preprogrammed micro-controller.

VEX ROBOTICS CONSTRUCTION ZONE

HEXBUG.COM £49.99 / $79.99

Hexbug has expanded massively on its product range since the early days of the original robot bug toy to include the VEX Robotics Construction Zone. With over 1,350 pieces, it's perfect for budding engineers and enthusiastic builders – especially those who are looking to up their game from simple LEGO-type construction sets. There are three separate builds that function just like their real-life counterparts, including tiny construction workers. The construction crane has an elevator and towers over your site at just above 60 centimetres. You can control its operations to lift and move objects wherever the crane can reach, while a dump truck complete with engine can haul parts across your construction site as a backhoe scoops the ground.

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WEIRD SCIENCE

WORDS **SCOTT DUTFIELD**

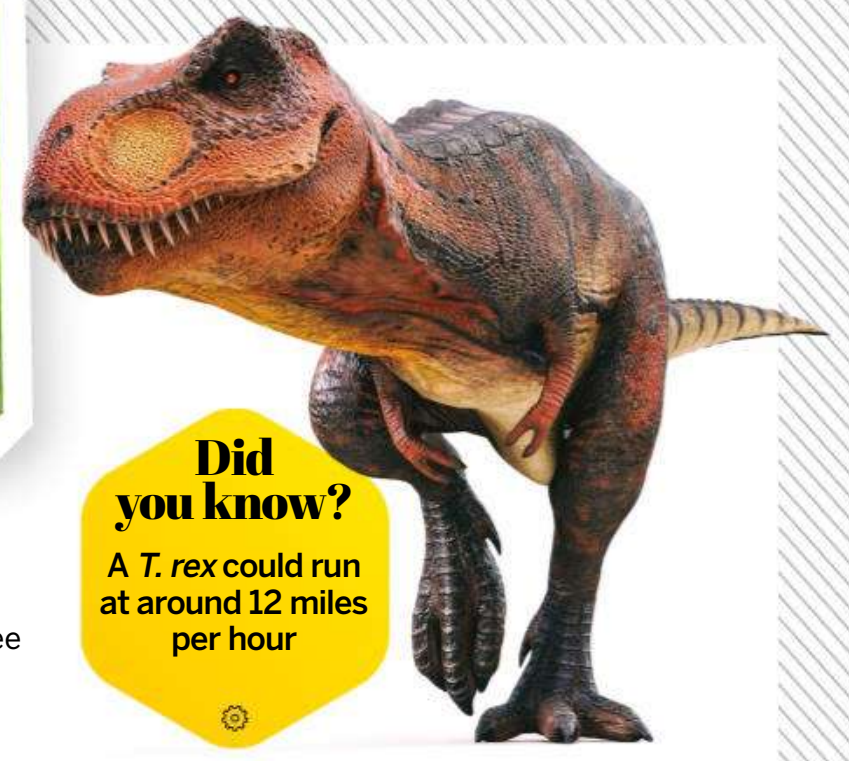
Discover the strange scientific studies that answer the questions you didn't know needed answering

WALKING LIKE A DINOSAUR

Given the right anatomy, chickens will walk like dinosaurs

How do you figure out how dinosaurs walked? For a group of researchers at the University of Chile and the University of Illinois, the answer came from artificially changing the anatomy of a distant living cousin: the chicken. Birds are the descendants of giant bipedal dinosaurs called theropods that roamed Earth millions of years ago. Some of the closest living avian relatives to the *T. rex* are chickens. But the two don't have quite the same anatomy, such as a chicken's lack of a heavy tail. It was thought that moving a living bird's centre of mass would recreate the posture of extinct dinosaurs, so a plunger-like tail was added to chicken test subjects to redistribute their centre of mass in a similar way to the *T. rex*.

In this study, researchers raised 12 domestic chicks for 12 weeks, split into three groups of four. One group of chickens was left alone as the control group, the second was given a weight to carry around on their backs and the third group was fitted with an experimental tail that weighed around 15 per cent of the chicken's overall mass. Over the 12-week period, the tail-wearing chickens had a more posteriorly located centre of mass than the other chickens, along with a more vertically orientated femur and elongated gait. The new chicken strut resembled that of a velociraptor walking through Jurassic Park.



Did you know?

A *T. rex* could run at around 12 miles per hour

RECREATING THE DINOSAUR WALK

How a chicken's body changes when you give it a tail

1 UNADAPTED CHICKENS
One group of chickens was reared without modifications as a control group.

2 WEIGHTED CHICKEN
A group was reared with extra back weight but no tail to see if weight over the pelvis alone changed their posture.

3 NEW TAIL
The experimental tail was made from wooden sticks inserted into a solid modelling clay base.

4 CENTRE
In chickens equipped with a new tail, the centre of mass moved from in front of the hindlimbs to the base of the tail.

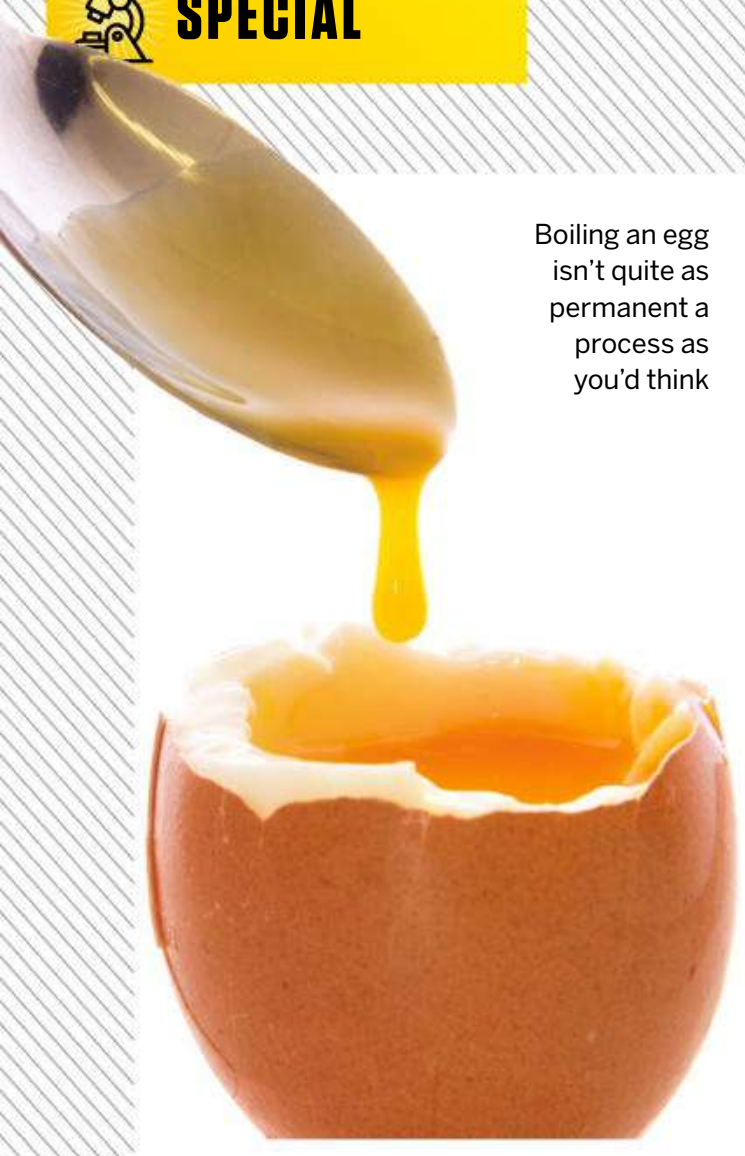
5 POSTURE
Among the tail-enhanced chickens, the orientation of the femur became more vertical and the knee joint was more extended.

Harvestmen have elongated legs that scientists wanted to understand better by making them shorter

MAKING DADDY SHORTLEGS

Harvestmen are small invertebrates that are often mistaken for spiders, with gangly legs to scale walls and ceilings. But what would they look like if they were shorter? Researchers at the University of Wisconsin isolated the genes linked to the growth of a harvestman with long flexible legs and turned them off in developing embryos. Over two years, researchers mapped out 580 million base pairs of a species of harvestman called *Phalangium opilio*. Comparing those base codes to those of another species, the fruit fly, helped pinpoint which portion of their genes were encoded for the growth of their legs. Using a process called RNA interference, they were able to disrupt the expression of the leg-growing genes. The results were newborn harvestmen with shorter and deformed legs. The newly stunted harvestman wasn't created just for the sake of it; the researchers will use the data to further understand arachnid development and their evolutionary journey.

© Getty / Alamy / Illustration by Adrian Mann



Boiling an egg isn't quite as permanent a process as you'd think

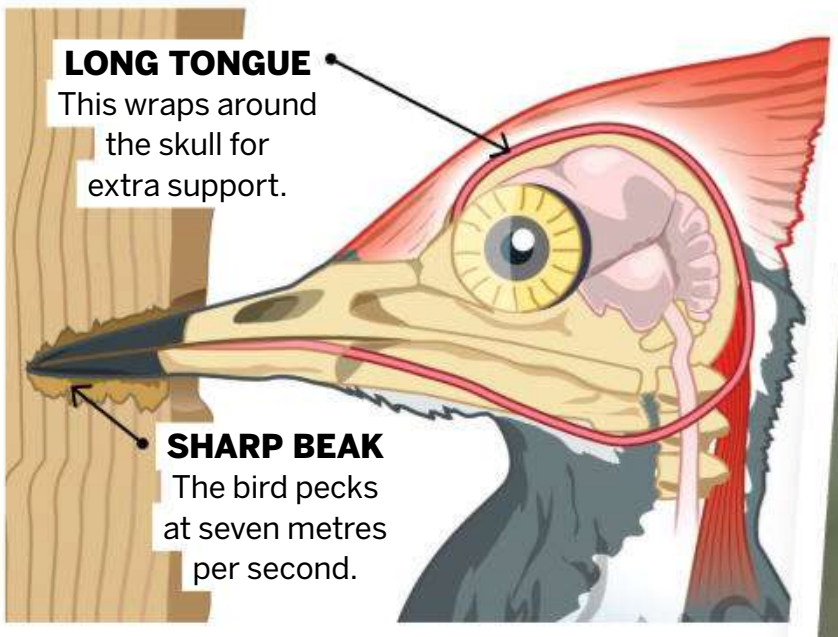
'UNBOILING' EGGS

With the help of a super spinning machine called a Vortex Fluidic Device (VFD), researchers at the Australian Academy of Science discovered a way to undo the work of a pot of boiling water. During the process of boiling an egg, knot-like proteins called lysozymes that make up the egg whites break apart and form new bonds with neighbouring proteins until they ultimately gel together into solid egg whites.

Researchers chopped up a boiled egg, added a chemical called urea – found in urine – and dissolved everything in water. The urea worked to break down the protein bonds again, but the lysozymes didn't yet reform into their previous knot-like state. Using the VFD, the eggy solution was then spun at speeds of 5,000 rotations per second in a test tube. As the solution span, the proteins were stretched and contracted until they returned to the knot-like shape they held before being boiled.

DO WOODPECKERS GET HEADACHES?

Because they spend most of their time hammering their heads against the trunks of trees, you might think that woodpeckers spend the rest of their time nursing a headache. However, scientists have discovered that their bodies are built for impact. In a 2002 study entitled 'Cure for a Headache', researchers at the University of California revealed that pileated woodpeckers (*Dryocopus pileatus*) have evolved specific anatomic features that stop their brains banging around their skull. Along with a thick skull made of spongy bone, there's a piece of cartilage that sits in the skull's mandible that partially cushions the impacts of repeated pecking. There are also dense muscles in the neck that contract one millisecond before impact to reduce the force applied to the skull. To prevent the acceleration of each strike tearing away at the bird's retinae and forcing their eyes to pop out, woodpeckers have strong eyelids that act like seat belts holding everything together.



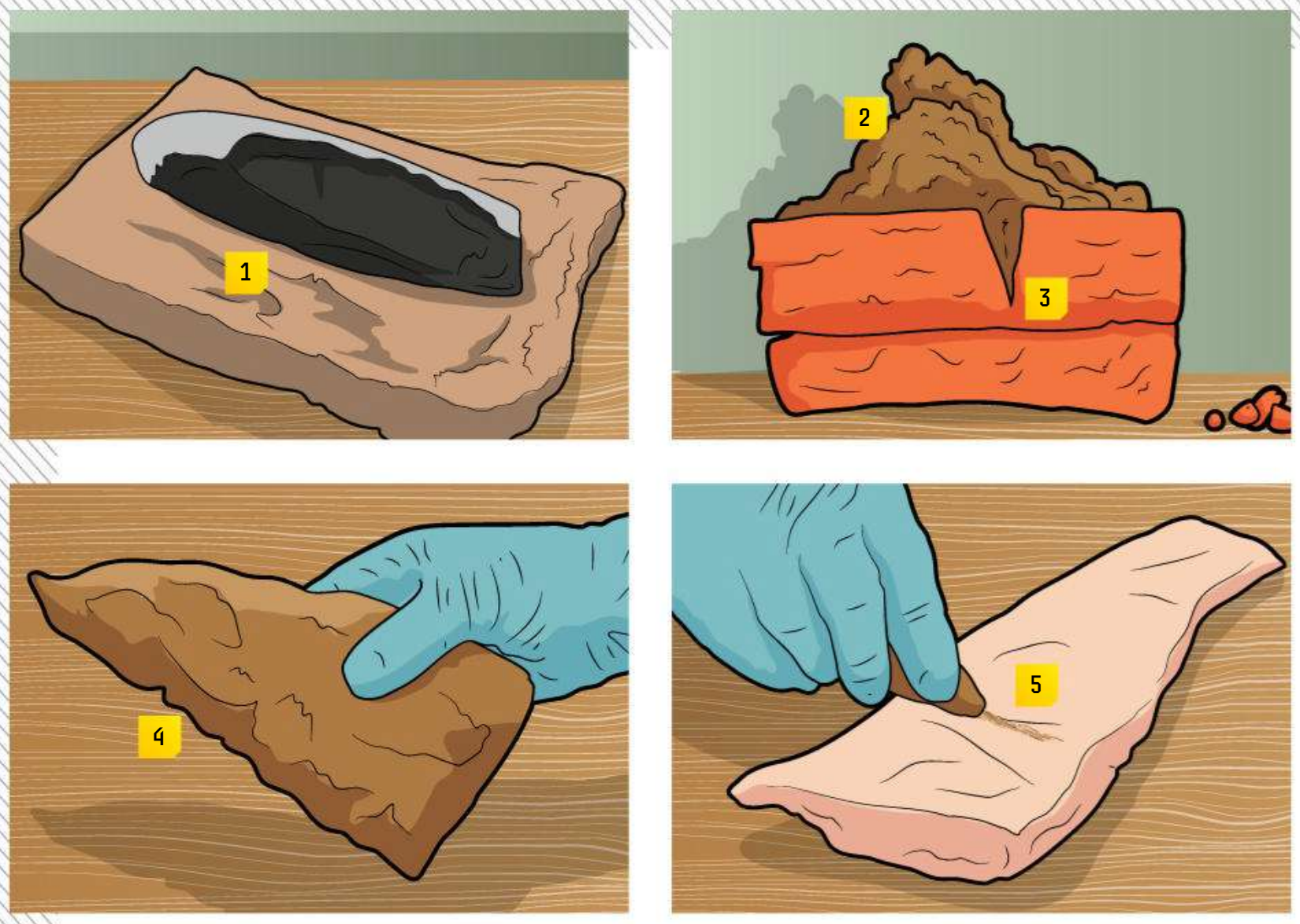
During mating season, male woodpeckers will drum on a tree up to 12,000 times a day

Rivers of molten jam might form a new world if Earth were made of blueberries

WHAT IF THE EARTH WAS A BLUEBERRY?

Have you ever wondered what the world would be like if it suddenly and unexpectedly transformed into a planetary pile of blueberries? Of course not, but a researcher at the University of Oxford's Future of Humanity Institute has, and the conclusion is quite explosive. Computational neuroscientist Anders Sandberg set out to answer what would happen if the entire Earth was instantaneously replaced with an equal volume of closely packed but uncompressed blueberries. What would happen from the perspective of a person on the surface? The answer is the unravelling of Earth physics as we know it. First, gravity would drastically reduce – you'd lose about 87 per cent of your weight in this new blueberry world. However, it wouldn't be long before the air trapped between the blueberries escaped and the berries collapsed under their own weight. The berries would eventually burst under pressure and form a planetary sphere of jam. As the blueberry-flavoured planet continued to collapse, the jam would heat up by 143 degrees Celsius. The oceans of boiling jam would lead to the creation of a fruity scented steam atmosphere, likely tinged blue. At the centre of the newly formed blueberry planet would be a compressed and extremely hot blueberry 'pulp ice'.

DID YOU KNOW? A finger snap takes seven milliseconds



FROZEN POOP KNIVES DON'T WORK

You might not be dumbfounded to discover that human waste isn't the best material for creating knives. However, a team of researchers at Kent State University and the Cleveland Museum of Natural History gave this study their best shot, just to double check. The unique research topic wasn't plucked from thin air, coming from a well known but likely apocryphal tale. In 1998 renowned anthropologist Wade Davis published *Shadows in the Sun*, in which he tells the story of an old Inuit man who refused to join a settlement and remained living alone on the ice. To force his hand, his family reportedly took away his tools in the hope he'd have no choice but to join the settlement. However, the man is said to have forged a knife from his own faeces that was sharp enough to kill and dissect a dog. The researchers wanted to put this story to the test by creating their own version. The resulting knife, however, was unable to cut through pig hide, muscle or tendons. Rather than cutting the flesh, the knife merely melted on contact, leaving faecal streaks behind... seems the story might have been total crap.

Did you know?

Poop is mostly water and bacteria, not digested food

MAKING A KNIFE MADE OF POOP

How scientists recreated one of the most unusual tools in history

1 CREATING MOULDS
Ceramic moulds were created by pushing carved stone blades into the potter's clay. The impressions of the blades were then fired in a kiln to harden.

2 RAW MATERIALS
One of the researchers ate an Arctic diet similar to the Inuit people for eight days. After the fourth day of the diet, 'raw materials' were collected.

3 PACKED
This 'raw material' was frozen at -20 degrees Celsius and packed tightly into the ceramic moulds.

4 SHARPENING
Once the knives were completely frozen, the edges were sharpened using a metal file before being buried again in -50 degree Celsius dry ice to ensure they were frozen.

5 CUTTING
The fully formed and frozen knives were then subjected to cutting tests on pig hides.

MOSQUITOS DON'T LIKE SKRILLEX

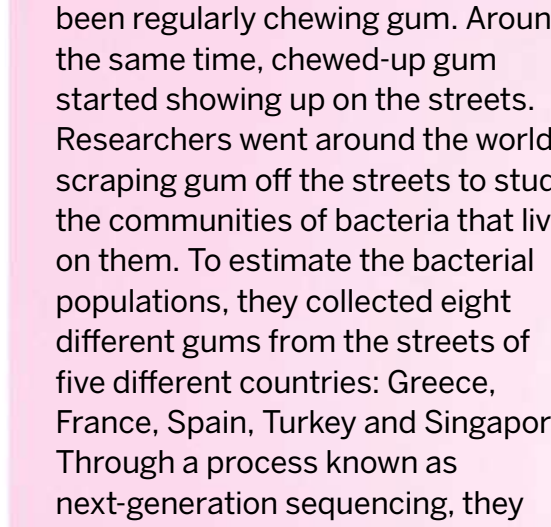
If you're a big fan of a certain kind of electronic dance music, there's a chance you might not be bothered by pesky mosquitoes quite so often. As bloodthirsty insects, mosquitoes transmit deadly diseases such as malaria, yellow fever and the Zika virus. In the fight to curb their appetite for human blood, researchers in Malaysia investigated the potential role that music could play as a deterrent and management tool for yellow fever mosquitoes (*Aedes aegypti*). While playing Skrillex's song *Scary Monsters and Nice Sprites*, researchers observed changes in how mosquitoes foraged, attacked a host and mated. What researchers discovered was that the mosquitoes that were exposed to Skrillex were less likely to feed on a host and visited a host less often when compared to a group of mosquitoes that weren't exposed to the music. Mosquitoes also mated less often while listening to Skrillex.

Skrillex might have won awards, but not the hearts of mosquitoes

© Alamy / Getty / Illustrations by Ed Crooks

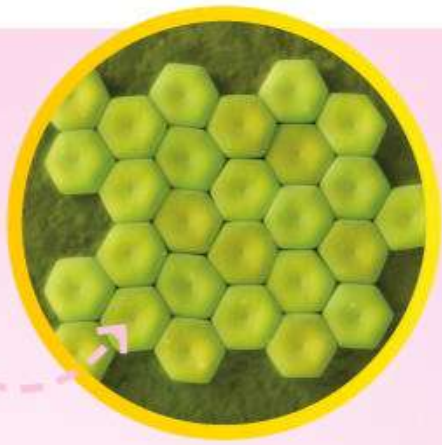
EXPLORING THE BACTERIOME OF FOOTPATH CHEWING GUM

Since the late 1960s people have been regularly chewing gum. Around the same time, chewed-up gum started showing up on the streets. Researchers went around the world scraping gum off the streets to study the communities of bacteria that live on them. To estimate the bacterial populations, they collected eight different gums from the streets of five different countries: Greece, France, Spain, Turkey and Singapore. Through a process known as next-generation sequencing, they were able to identify the genetic information of a whole host of different bacteria species. The gum with the highest bacterial biodiversity was found in Singapore and boasted 427 different species. The researchers claim their work has implications in the fields of criminology, contagious disease control and waste management. Part of the study was dedicated to evaluating the biodegradable abilities of gum-bound bacteria, of which there is some evidence for.



LIVING ON GUM

Some of the bacteria that commonly make a home on pavement chewing gum



ACINETOBACTER
This group of bacteria is widespread. They are the most common causes of infections in humans.

PSEUDOMONAS
Common bacteria found in the environment, they can cause illness to those with a weakened immune system.

SPHINGOMONAS
A rod-shaped bacterium that rarely causes infection in humans and is widely found in soil and water.

DEINOCOCCUS
Found in organic material such as sewage and in meat, these hardy bacteria are remarkably resistant to a range of radiations, including ionising and ultraviolet radiation.

THE OPPOSITE-ITCH MIRROR SCRATCH

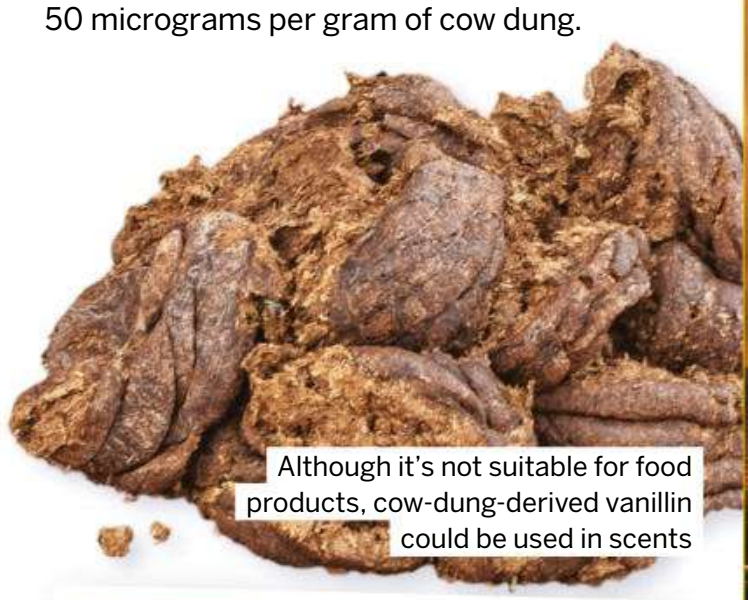
The next time you get an itch on your arm, run to the mirror and scratch the opposite arm and you might find the itch disappears without being scratched. Researchers at the University of Luebeck in Germany injected 26 volunteers with itch-inducing chemicals into their forearms. They then placed a red dot over the injection site and a corresponding dot on the opposite arm in the same position. A mirror was then placed between the arms, obscuring the participants' views of their itch-induced right arms. Participants were then asked to look at the reflection of the non-itchy left arm in the mirror while a researcher scratched the concealed itchy right arm. Researchers then switched arms, scratching only the non-itchy left arm, and surprising the participants with perceived relief from the itch. There are some practical uses for the discovery, including the development of treatments for chronic itching conditions.

Mirrors can confuse how we locate itches on our bodies

DID YOU KNOW? It takes 1,000 licks to reach the centre of an average-sized lollipop

VANILLA ESSENCE CAN BE EXTRACTED FROM COW PATS

Vanillin is a chemical compound used in medicines, scents and flavourings. Typically, vanillin is extracted from the vanilla bean plant. However, a small portion of the world's vanillin comes from an alternative source, such as lignin, a wood-derived polymer. In 2008, a group of Japanese researchers found an unlikely potential source of vanillin and developed a way to extract it from livestock excrement. To extract the vanillin, the researchers combined one gram of cow pat with water, placed it into a reactor and heated the manure in intervals up to 300 degrees Celsius under high pressure for 60 minutes. During this time, the chemical compositions of the slurry were analysed using a chromatography device, a machine that separates the chemical components of a solution. At temperatures above 200 degrees Celsius, vanillin was detected, amounting to 50 micrograms per gram of cow dung.



Although it's not suitable for food products, cow-dung-derived vanillin could be used in scents

Godzilla stomping through San Francisco in the 2014 motion picture

DOG FLEAS JUMP HIGHER THAN CAT FLEAS

Two different species of fleas can live on our favourite household pets. *Ctenocephalides canis* live on dogs, whereas *Ctenocephalides felis* reside on cats. Researchers at the National Veterinary School of Toulouse, France, wondered which of the two could jump the highest. To find an answer, the researchers put ten of the species' finest athletes to the test in a series of jumping trials that involved jumping out of tubes at different heights. The species that came out on top was the *C. canis* team for the mean highest jump. It was a close call, but the highest jump for *C. felis* was 17 centimetres, whereas the dog fleas outperformed cat fleas by leaping to a mean height of 25 centimetres.

Ctenocephalides canis fleas can outjump their feline counterparts

Did you know?

Fleas can survive without food for two weeks

ANXIETY MADE GODZILLA GROW

Godzilla has been stomping on cities since 1954. Over the years there have been many different versions of the giant tyrannical lizard, and each one has grown incrementally. At his inception, Godzilla was 50 metres tall. However, in the latest depiction seen in *Godzilla: King of the Monsters*, he has grown to be 119.8 metres tall. In 2019, researchers at Dartmouth College in New Hampshire published a paper to explain why Godzilla has evolved 30 times faster than any real organism on Earth. Researchers concluded that cultural anxiety was likely the cause of Godzilla's rapid growth in his movies. Using US military spending as a proxy for the nation's anxiety, researchers found strong correlations between spending and the size of Godzilla. "Whether reacting to geopolitical instability, a perceived threat from terrorists or simply fear of 'the other,' many democracies are electing nationalist leaders, strengthening borders and bolstering their military presence around the world," they wrote.

© Alamy / Getty

IG NOBEL WINNERS

Meet the Ig Nobel Prize winners of 2022

A month before the prestigious Nobel Prizes are handed out to some of the world's greatest minds and their pioneering work, another less groundbreaking awards ceremony takes place. Founded in 1991 by journal editor Marc Abrahams, the Ig Nobel Prize parodies its namesake with "achievements that make people laugh, then think". Here are the winners of the latest awards, given to STEM research.

HOW CONSTIPATION AFFECTS SCORPION MATING

Biology Prize

Researchers at the Universidade de São Paulo in Brazil took a deep dive into the mating success of male scorpions (*Ananteris balzanii*) that amputate their own tails, the process of which also permanently removes their anus. As a defensive response to predators known as autotomy, many scorpions will purposefully detach their tails in the hope that predators will be satisfied with a portion of the scorpion, allowing the rest of the animal to escape. There is one drawback, however. They also lose the end of their digestive tract and their anus. Without the ability to defecate, tailless scorpions will die from constipation after several months. This still leaves plenty of time to find a mate, if they are quick enough to find them. By looking at the maximum running speed of automised scorpions, researchers found that the loss of a tail and the inability to poop didn't slow scorpions enough to prevent them from finding a mate.

LOVE AT FIRST SIGHT MAKES HEARTS SYNCHRONISE

Applied Cardiology Prize

Scientists in the Netherlands investigating the physiological dynamics of attraction discovered that love is in the air when two hearts beat as one. Heterosexual participants took part in a series of real 'blind dates' in a cabin set up by the researchers. During each date, the participants were fitted with an array of sensors to monitor their bodies' responses to prospective partners. The sensors used included a pair of smart glasses to monitor eye movements, laughing and smiling, as well as a heart rate monitor and an electrodermal sensor to track skin perspiration. Couples were asked to firstly look at each person and rate them on attractiveness, then talk freely for two minutes, followed by another rating, then instructed to look at each other for another two minutes without talking.

Among the couples who found each other attractive, their heart rates synchronised, even to the point that if one person's heart rate increased, the other's sped up to meet it.

DID YOU KNOW? Horses prefer banana-flavoured grain to carrots

HOW DUCKLINGS SWIM IN FORMATION

Physics Prize

Researchers at Jiangsu University of Science and Technology in China have answered the age-old question of why ducklings swim in a line. Mother ducks and ducklings are often seen paddling along the river in a single-file line. In 1994, a biologist called Mark Fish suggested this was to conserve energy for the ducklings, which researchers have now confirmed. Ducklings instinctively follow their mother while in the water and position themselves in a line behind her tail. The duckling closest to her begins to ride the waves she creates behind her, reducing the amount of 'water drag' that ducklings have to paddle against to keep up. Moving down the line, each duckling will continue to 'ride the wave', using less energy to move forward the farther down the line they are.

Did you know?

Ducks are omnivores, eating fish and insects as well as plants

THE BEST WAY TO TURN A DOORKNOB

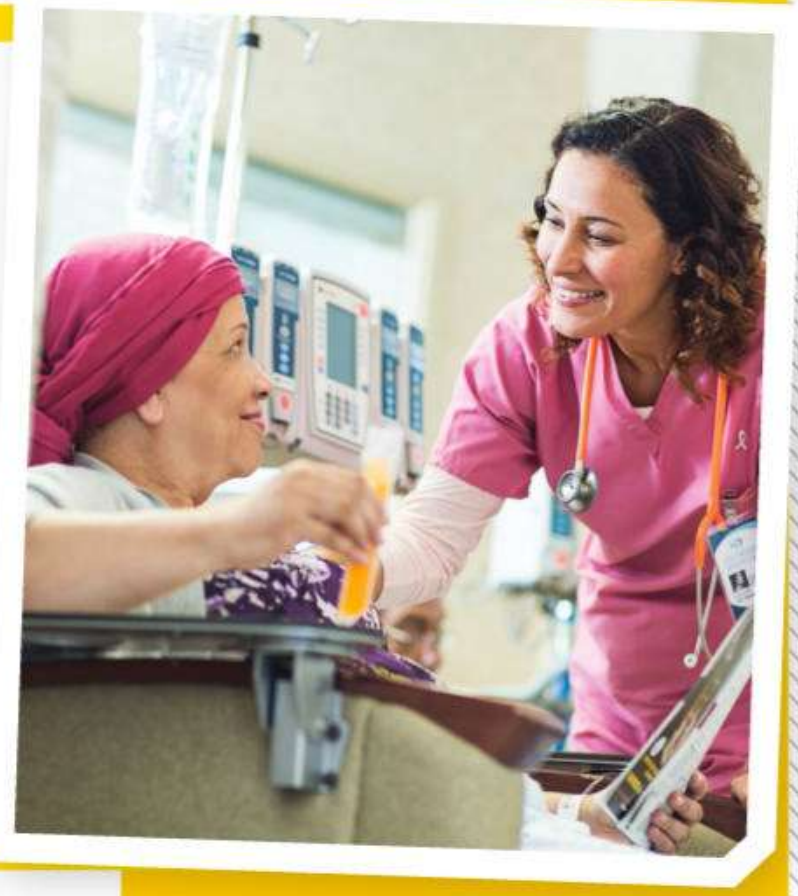
Engineering Prize

Japanese industrial design researchers tested out the most efficient way to turn a doorknob. 32 participants were tasked with turning 47 assorted knobs. The results indicated that for a knob wider than one centimetre, the turner would need to use at least three fingers. For doorknobs that exceed two-and-a-half and five centimetres, the fingers required to turn the knob increases to four and five respectively. It was also identified that the two most used fingers for opening door knobs are the thumb and pointer finger. The researchers simply concluded that the bigger the doorknob, the more fingers you need to grab it. Researchers will use the data from the study to design and manufacture more ergonomic doorknobs, particularly for elderly people and those with physical difficulties.

ICE CREAM'S POSITIVE EFFECTS ON CHEMOTHERAPY

Medicine Prize

A common side effect of chemotherapy and radiotherapy, oral mucositis causes pain and inflammation in the mouth and gut during some treatments. To help prevent mucositis, doctors use ice through cryotherapy. However, researchers at the University of Warsaw in Poland hypothesised that shop-bought ice cream could replace the cryotherapy step during some treatments. Currently, ice cream is used to help treat the symptoms of mucositis, but not as a preventive method. The study called on 74 patients undergoing a particular cancer treatment called melphalan infusion. 52 patients received ice cream cryotherapy during treatment, and the remaining 22 did not. The researchers discovered that only 15 out of 52, or 28.85 per cent, of the patients that received ice cream cryotherapy developed mucositis, whereas 13 of 22, or 59.09 per cent, of those that received none developed the condition.



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SPECIAL

SCIENTIFICALLY PROVEN

CHICKENS WILL PECK IMAGES OF FACES THAT HUMANS FIND BEAUTIFUL

1.82 MILLIGRAMS
The average mass of belly button fluff

THREE KILOGRAMS

Every mammal that weighs more than a small house cat empties its bladder in 21 seconds

ELASTIC BANDS LAST LONGER ONCE THEY'VE BEEN REFRIGERATED

45,000 WORDS

A typical pencil can write an entire novella before running out of graphite

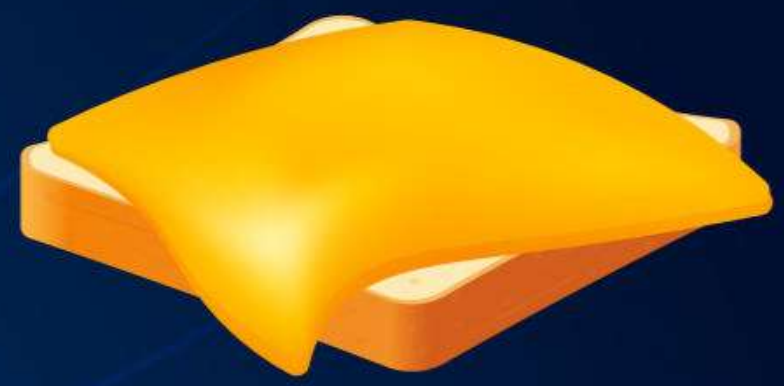
60 KILOPASCALS

Adult penguins generate huge pressures to expel waste similar in viscosity to olive oil

HAPPY GAMBLERS BET MORE MONEY AFTER HOLDING A CROCODILE

DID YOU KNOW? Stomach acid can dissolve a razor blade

PEOPLE WHO THINK THEY HAVE SMELLY FEET DO, AND THOSE THAT DON'T, DON'T



THE FORMULA FOR PERFECT CHEESE ON TOAST

50 GRAMS OF SLICED CHEDDAR

ONE SLICE OF WHITE BREAD, TEN MILLIMETRES THICK

GRILL AT 115 DEGREES CELSIUS

THE DISTANCE BETWEEN BREAD AND GRILL SHOULD BE 18 CENTIMETRES

COOK FOR FOUR MINUTES

YOU ARE LESS LIKELY TO SPILL COFFEE WHILE WALKING BACKWARDS

711

A 75-kilogram adult would die after eating this many 45-gram chocolate bars in one sitting

AT A TYPICAL WALKING SPEED OF 3.1 MILES PER HOUR, IT WOULD TAKE 91 DAYS TO WALK AROUND THE MOON

THERE'S A NEARLY 50 PER CENT CHANCE THAT YOUR REMOTE CONTROL IS STUCK BETWEEN THE SOFA CUSHIONS

© Getty

SCIENCE

WHAT ARE WEATHER BALLOONS?

These high-altitude inflatables carry the tools needed to produce weather forecasts

WORDS **AILSA HARVEY**

At around 900 sites around the world, balloons are launched twice a day. These inflatable apparatuses are weather balloons, providing regular updates on conditions above the ground. Carrying instruments that can analyse atmospheric data, weather balloons are a primary tool used to produce daily weather forecasts. During their flights, the instruments send information to meteorologists such as the surrounding air pressure, the wind conditions and precipitation levels. The balloons are made of a synthetic rubber called neoprene, which is 0.051 millimetres thick at ground level. As the apparatuses gain altitude, the low pressure causes the gas to expand, stretching the neoprene to a thickness of just 0.0025 millimetres. Weather balloons can vary in diameter, usually between 1.4 and 2.4 metres. This size depends on how heavy the apparatuses and instruments being carried are and the altitude that meteorologists are aiming to analyse.

Did you know?

Around 20 per cent of radiosondes can be reused

A meteorologist launching a weather balloon. In one hand he is holding the balloon, with the radiosonde device in the other

While each flight lasts only a couple of hours, the manufacturing process of these balloons ensures that they can withstand conditions far more extreme than at their launch point on the ground. This includes temperatures as low as -95 degrees Celsius and air pressures as low as a few thousandths of what's experienced at ground level. But with so many weather balloons being launched to provide us with weather predictions, why are they rarely seen in the sky or falling down near us? This is because the launch sites are chosen for their open space and limited obstacles. Many weather balloons are released at airfields where there are no mountains or tall buildings to bring them down prematurely. At the end of a flight, meteorologists will aim to reduce the damage to the apparatus as it lands. Those that are retrieved intact can then be used for future readings.

THE FIRST BALLOONS

This weather-observation device was first launched in 1896 by a French meteorologist named Léon Teisserenc de Bort. The instruments attached to early weather balloons could measure barometric pressure, temperature and humidity. However, there was no parachute attached that could control the balloon's fall at the end of a flight. Instead the open-bottomed balloons deflated and descended when the air temperature dropped.

In these early experiments, scientists had little control over the movements of the balloon. Sometimes the instruments couldn't be retrieved because they had drifted too far from the launch site. Today materials are carefully controlled, and closed balloons are used so that when they reach a certain altitude, they drop again and can be more easily retrieved.

Meteorologist Léon Teisserenc de Bort lived between 1855 and 1913

DID YOU KNOW? Before weather balloons were used to measure upper air conditions, kites with thermometers attached were used

UP IN THE AIR

The launch-to-landing operations of this high-altitude meteorological device

UNDER PRESSURE
Weather balloons remain in the air for around two hours. They can rise up to around 30,500 metres before popping due to low pressures.

SLOW DESCENT
When weather balloons pop, a parachute is deployed. This slows the fall back to ground level and prevents damage to instruments.

FLOATING AT ALTITUDE
As the weather balloon floats to its maximum altitude, it expands to four times its size due to atmospheric pressure.

WEATHER MEASUREMENTS
An instrument called a radiosonde is attached to the balloon. Its sensors detect weather conditions, while its transmitter delivers live data to the ground.

CONSTANT COMMUNICATION
Meteorological values detected by the sensors are converted into a code and transmitted to the radio station as radio signals.

HELIUM LIFT
Either helium or hydrogen gas is used to make the weather balloon rise because they are lighter than air. Helium is used more than hydrogen because it isn't flammable.

RADIO STATION
The data received at the radio station is used to make weather forecast models and predict storms.

5 FACTORS MEASURED

1 TEMPERATURE
A radiosonde has a thermistor to measure the temperature of the air surrounding the balloon.

2 HUMIDITY
A hygristor measures humidity. This sensor has a film of lithium chloride, a compound that has varying electrical resistance based on humidity.

3 PRESSURE
An aneroid barometer records air pressure. Inside is air that expands or shrinks based on the pressure.

4 WIND SPEED
The balloon uses GPS to track its position. Changes in location over time provides data on wind speed.

5 WIND DIRECTION
The exact location and journey taken by the balloon during its flight shows which direction the wind is blowing.

© Alamy / Unknown author

SCIENCE

HOW FREEDIVERS PLUNGE SO DEEP

Take a dip into this extreme sport and see what drives divers deeper into the underwater world

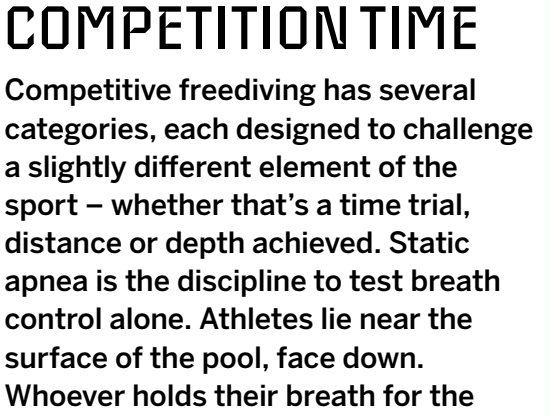
WORDS **AILSA HARVEY**

Breathing techniques are methods used by many to instil calmness into the body and mind. Breathing draws in life-essential oxygen, which fuels every one of our cells. For some, however, true peace can be found 100 metres below the ocean's surface. Freediving is an underwater sport and activity that includes any dive taken without any breathing apparatus. It's also part of ancient history, and evidence shows that people have been freediving for over 9,000 years. Our ancestors relied on diving underwater to harvest valuable natural resources, including sea sponges found on the seafloor, which communities used as padding for helmets and as cleaning tools. Ancient divers also gathered food underwater and hunted for precious pearls.

Did you know?

Freedivers have recorded heart rates of ten beats per minute

Today the sport may seem simplistic, as its participants usually wear just a wetsuit, mask and fin. But to be an expert freediver requires exceptional fitness and knowledge of your body's personal capabilities like breath-holding, as allowing oxygen levels to get too low in the body's tissues leads to hypoxia. This is the term given to severely low levels, which can result in a person losing consciousness. One of the most important rules of freediving is to always have a 'buddy'– someone who dives with you and can assess when danger is near.



Many freediving disciplines do not require deep water

COMPETITION TIME

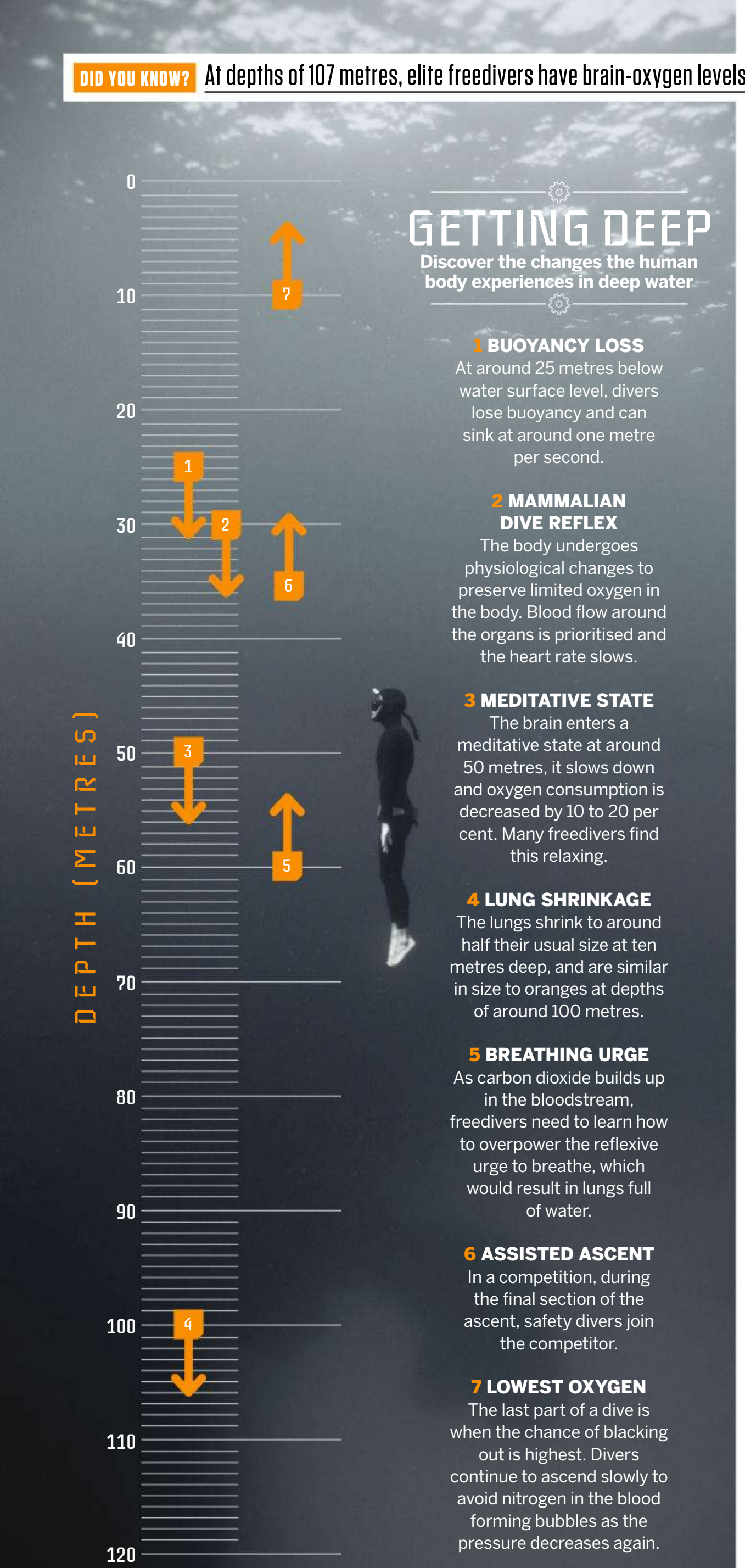
Competitive freediving has several categories, each designed to challenge a slightly different element of the sport – whether that's a time trial, distance or depth achieved. Static apnea is the discipline to test breath control alone. Athletes lie near the surface of the pool, face down. Whoever holds their breath for the longest time while still remaining in control after surfacing wins. In the distance category, athletes are judged based on how far they can travel in a pool on one breath. These competitions include swimming with a monofin, one large fin; bi-fins, two smaller fins, and no fins. Depth competitions take place at sea and either require athletes to meet a predetermined depth or to set new records with an unlimited depth challenge. In these competitions, athletes dive next to a rope that they can use to guide themselves back to the surface.

IS FREEDIVING DANGEROUS?

As freediving involves any dive underwater in a single breath, for some freedivers their next lung full of air is never too far away. However, freediving is still classed as an extreme sport, and for good reason. When over 100 metres below the surface, the pressure poses some serious risks. One of the main dangers is nitrogen narcosis. This is when the concentration of nitrogen in the bloodstream increases the deeper you dive. At the surface, the air you breathe is made up of 78 per cent nitrogen, but this doesn't enter the bloodstream until it's under high pressure. The deeper someone dives, the more nitrogen can enter the blood, giving the diver similar symptoms to someone who is drunk.

Guide ropes help make freediving controlled

DID YOU KNOW? At depths of 107 metres, elite freedivers have brain-oxygen levels lower than those of seals



GETTING DEEP

Discover the changes the human body experiences in deep water

1 BUOYANCY LOSS
At around 25 metres below water surface level, divers lose buoyancy and can sink at around one metre per second.

2 MAMMALIAN DIVE REFLEX
The body undergoes physiological changes to preserve limited oxygen in the body. Blood flow around the organs is prioritised and the heart rate slows.

3 MEDITATIVE STATE
The brain enters a meditative state at around 50 metres, it slows down and oxygen consumption is decreased by 10 to 20 per cent. Many freedivers find this relaxing.

4 LUNG SHRINKAGE
The lungs shrink to around half their usual size at ten metres deep, and are similar in size to oranges at depths of around 100 metres.

5 BREATHING URGE
As carbon dioxide builds up in the bloodstream, freedivers need to learn how to overpower the reflexive urge to breathe, which would result in lungs full of water.

6 ASSISTED ASCENT
In a competition, during the final section of the ascent, safety divers join the competitor.

7 LOWEST OXYGEN
The last part of a dive is when the chance of blacking out is highest. Divers continue to ascend slowly to avoid nitrogen in the blood forming bubbles as the pressure decreases again.

PROFESSIONAL FREEDIVER GEORGINA MILLER

British freediver Georgina Miller ranked in the top six for all freediving disciplines in 2022 and can hold her breath for over seven minutes. Learn with her at aquacityfreediving.com

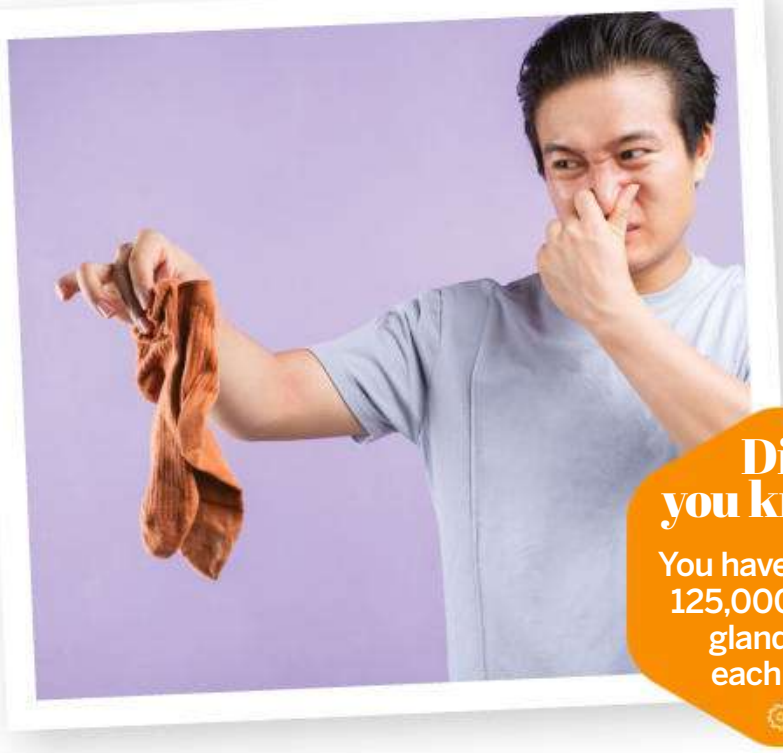
What do you enjoy about deep diving?
Deep diving is so much to do with stillness, understanding what is happening internally. It's a lot like meditation. It's the most amazing feeling being deep underwater; it gives you a huge appreciation and respect for the wilderness that we are in. I think a lot of deep freedivers feel, in those moments below, that you are at one with the ocean, and it's very peaceful. Taking a really progressive approach to it and training with a good safety system in place means that it's not scary or risky, so it gives you the freedom to explore what you can do.

What differences can you feel in your body?
Freediving keeps you fit and healthy. A lot of time is spent training and preparing mentally and physically. When it comes to how it feels being underwater, it's calm. Your heart rate slows and you lose your edges physically.

How do you train your body before diving?
Deep diving needs a very gentle and progressive approach. Helping develop thoracic [ribcage] flexibility is useful, and being fit for the swim up. There is aerobic fitness training and carbon dioxide tolerance, but mainly for me it's about equalisation: making sure to balance the pressure in your ears.

How important is it to learn about the science of freediving before practising it?
Really important. It keeps you safe if you can understand what's going on physically and in the space around you. It also anchors you in technique to maximise your training. I would advise anyone to take a course with a qualified instructor, not just for safety but to get off to a good start with it. Once beginners get to grips with the science of the sport, it makes the physical sensations much easier to deal with.

© Getty / Georgina Miller



Did you know?

You have around 125,000 sweat glands on each foot

PRIME LOCATION
Between the toes is usually the sweatiest part of a foot because skin surfaces are close together.
SWEAT GLANDS
The foot has more sweat glands than any other part of the body.

BREVIBACTERIUM
This bacterium thrives in the damp, salty environments found on feet.

WHY SOME FEET SMELL CHEESY

Discover the bacteria that brews inside your socks

WORDS **AILSA HARVEY**

One of the most common words used to describe smelly feet is ‘cheesy’. But in actual fact it’s cheese that takes on the stench of unclean feet. The type of bacteria naturally found on the foot which is responsible for foot odour is called brevibacterium, and this is also a vital component in cheese-making. *Brevibacterium* is present in animal milks and is specifically added to the surfaces of cheeses to develop a strong flavour and texture. It’s the bacteria that gives many cheeses a smell comparable to sweaty feet.

This powerful smell is much less enticing when it’s emanating from a pair of feet. It’s caused by bacteria that feed on salts released by the body to produce a rancid-smelling acid. Another example of a bacterium that multiplies on sweaty feet is *Staphylococcus epidermidis*. This bacterium turns the sweat on feet into propanoic acid, adding to the pungency of an unclean foot. There are many reasons why some people’s feet smell more than others, including hormonal changes in teenagers and medical conditions that cause feet to be unusually sweaty.

Bacteria aren’t always to blame, however. Fungi, which also thrive in the warm and sweaty confines of a socked foot, can cause an infection commonly known as athlete’s foot. This infection can make your foot feel itchy and cause it to turn red and swollen. Instead of using the common antibacterial products to remove foot odour, antifungal creams and sprays are needed to combat fungal infections.

Like your feet, Muenster cheese has *brevibacterium* on it

CHEESE FACTORY

Meet the bacteria responsible for the pungent foot smell

ELIMINATE THE ODOUR

How can you prevent your feet from releasing a foul smell? The number one way to keep your feet fresh is to prioritise washing. Using antibacterial soap works best, and washing needs to be maintained at least once a day. Make sure to target the toes and toenails. Cutting toenails short limits the places where bacteria can linger. You might not be able to control the fact that you need to wear shoes all day, but you can pay attention to materials when buying footwear. Keep footwear breathable by choosing cotton and other natural fabrics.

Dry your feet after washing to reduce bacterial or fungal growth

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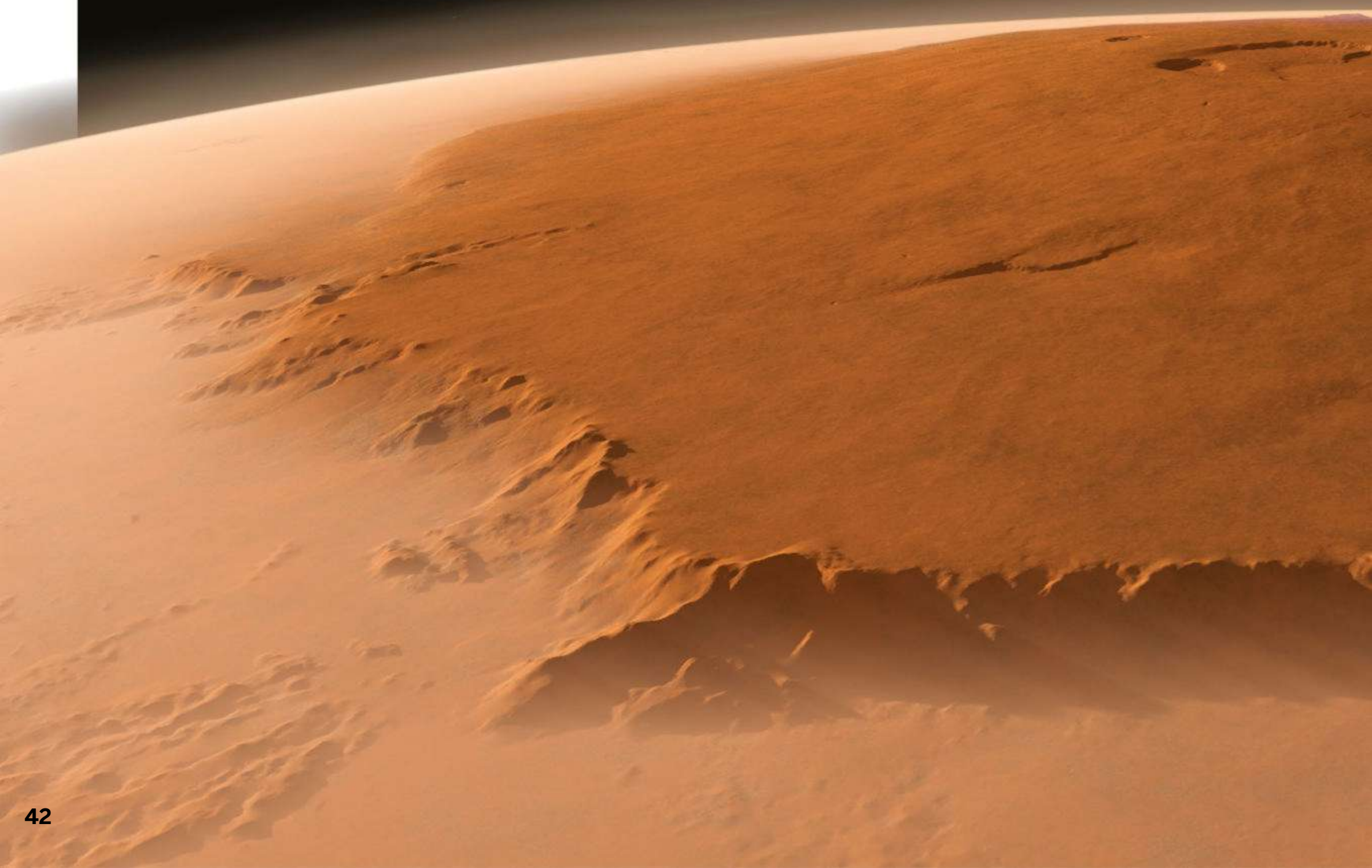
GIANT MARTIAN VOLCANO

Mars' Olympus Mons is three times as high as Everest, but how did it get so big?

WORDS **ANDREW MAY**



DID YOU KNOW? Other large volcanoes in the Tharsis region include Ascraeus Mons, Pavonis Mons and Arsia Mons

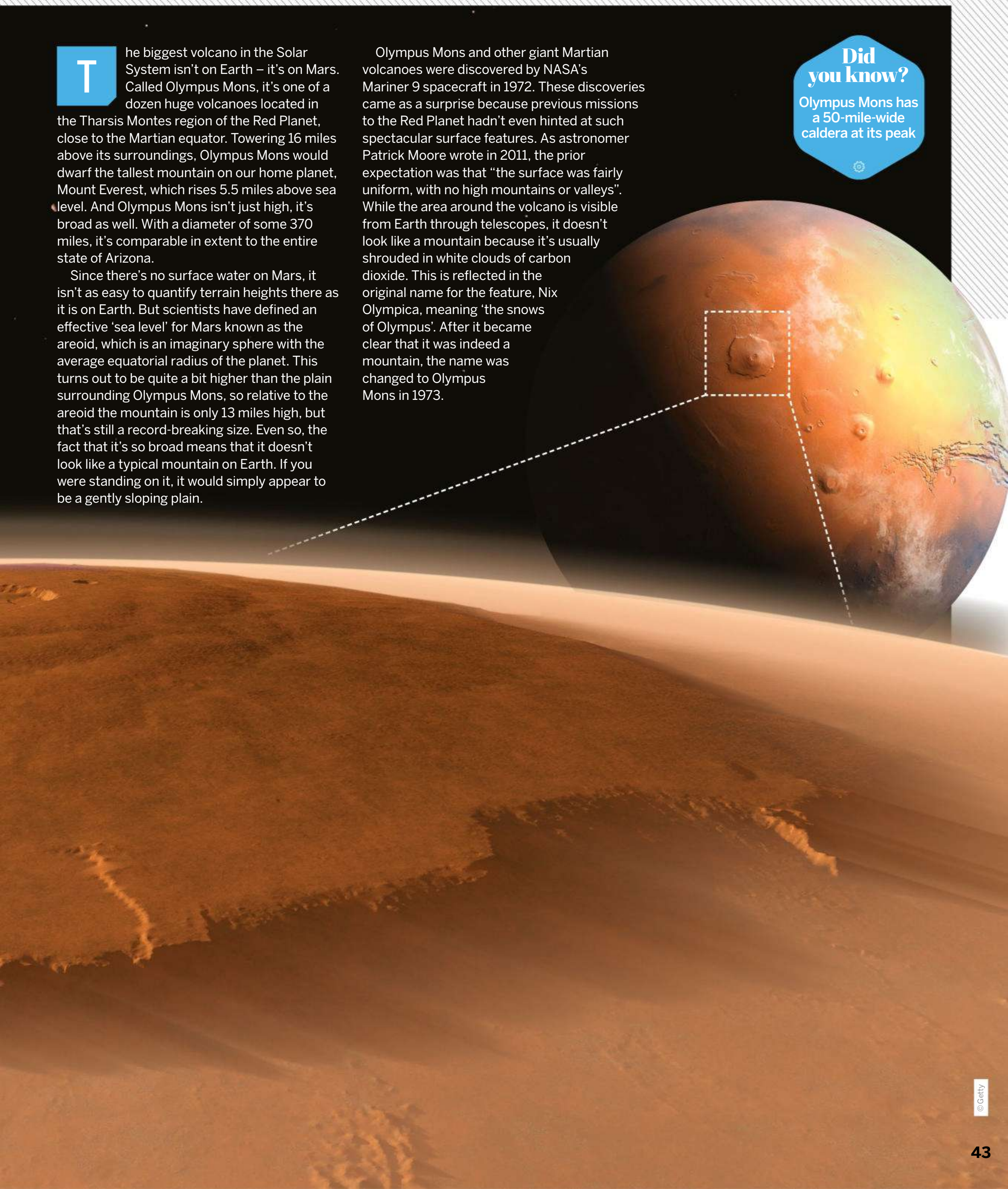
The biggest volcano in the Solar System isn't on Earth – it's on Mars. Called Olympus Mons, it's one of a dozen huge volcanoes located in the Tharsis Montes region of the Red Planet, close to the Martian equator. Towering 16 miles above its surroundings, Olympus Mons would dwarf the tallest mountain on our home planet, Mount Everest, which rises 5.5 miles above sea level. And Olympus Mons isn't just high, it's broad as well. With a diameter of some 370 miles, it's comparable in extent to the entire state of Arizona.

Since there's no surface water on Mars, it isn't as easy to quantify terrain heights there as it is on Earth. But scientists have defined an effective 'sea level' for Mars known as the areoid, which is an imaginary sphere with the average equatorial radius of the planet. This turns out to be quite a bit higher than the plain surrounding Olympus Mons, so relative to the areoid the mountain is only 13 miles high, but that's still a record-breaking size. Even so, the fact that it's so broad means that it doesn't look like a typical mountain on Earth. If you were standing on it, it would simply appear to be a gently sloping plain.

Olympus Mons and other giant Martian volcanoes were discovered by NASA's Mariner 9 spacecraft in 1972. These discoveries came as a surprise because previous missions to the Red Planet hadn't even hinted at such spectacular surface features. As astronomer Patrick Moore wrote in 2011, the prior expectation was that "the surface was fairly uniform, with no high mountains or valleys". While the area around the volcano is visible from Earth through telescopes, it doesn't look like a mountain because it's usually shrouded in white clouds of carbon dioxide. This is reflected in the original name for the feature, Nix Olympica, meaning 'the snows of Olympus'. After it became clear that it was indeed a mountain, the name was changed to Olympus Mons in 1973.

Did you know?

Olympus Mons has a 50-mile-wide caldera at its peak



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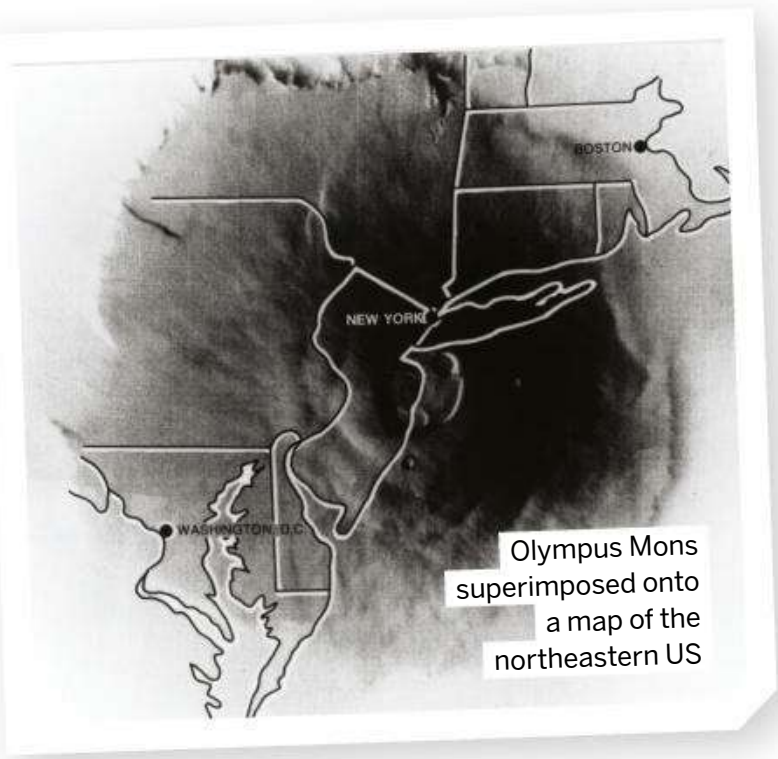
A NON-VOLCANIC MOUNTAIN ON MARS

Most large mountains on Mars have a volcanic origin like Olympus Mons. An exception is Mount Sharp, the mountain currently being explored by NASA's Curiosity rover. This rises from the centre of Gale crater. While much smaller than Olympus Mons, it's still a formidable 3.4 miles high – taller than Mont Blanc, the highest peak in Western Europe. In spite of this, it didn't have a name before the Curiosity mission. Its common name comes from the geologist Robert P. Sharp, who died in 2004, while its official name is Aeolis Mons. While Gale crater was formed by an asteroid impact around 3.7 billion years ago, the origin of the central mountain is more of a mystery. The best theory is that it was built up by wind-blown deposits of sand and sediment.

Mount Sharp seen from a distance by the Curiosity rover soon after landing on Mars



Olympus Mons superimposed onto a map of the northeastern US

It may seem strange that Mars, a smaller planet than Earth, has higher mountains. But a smaller planet has weaker gravity, which means it's less able to smooth out irregularities on the surface. The asteroid Vesta, which is just 329 miles in diameter, has a mountain near its south pole which is over 12 miles in height, rivalling Olympus Mons. That mountain, which rises from the centre of an enormous crater called Rheasilvia, was produced by a past impact event, and the same is true of most of the mountains on our Moon. What we see today as lunar 'mountain ranges' were originally formed as the rims of giant impact craters. On the other hand, most mountains on Earth were produced as the result of geological processes. The largest mountain ranges were created when two tectonic plates – slowly moving portions of the planet's crust – crashed into each other. This is true of the Himalayas – the chain of mountains containing Mount Everest – which were formed when the Indian subcontinent collided with the rest of Asia around 40 million years ago.

Did you know?

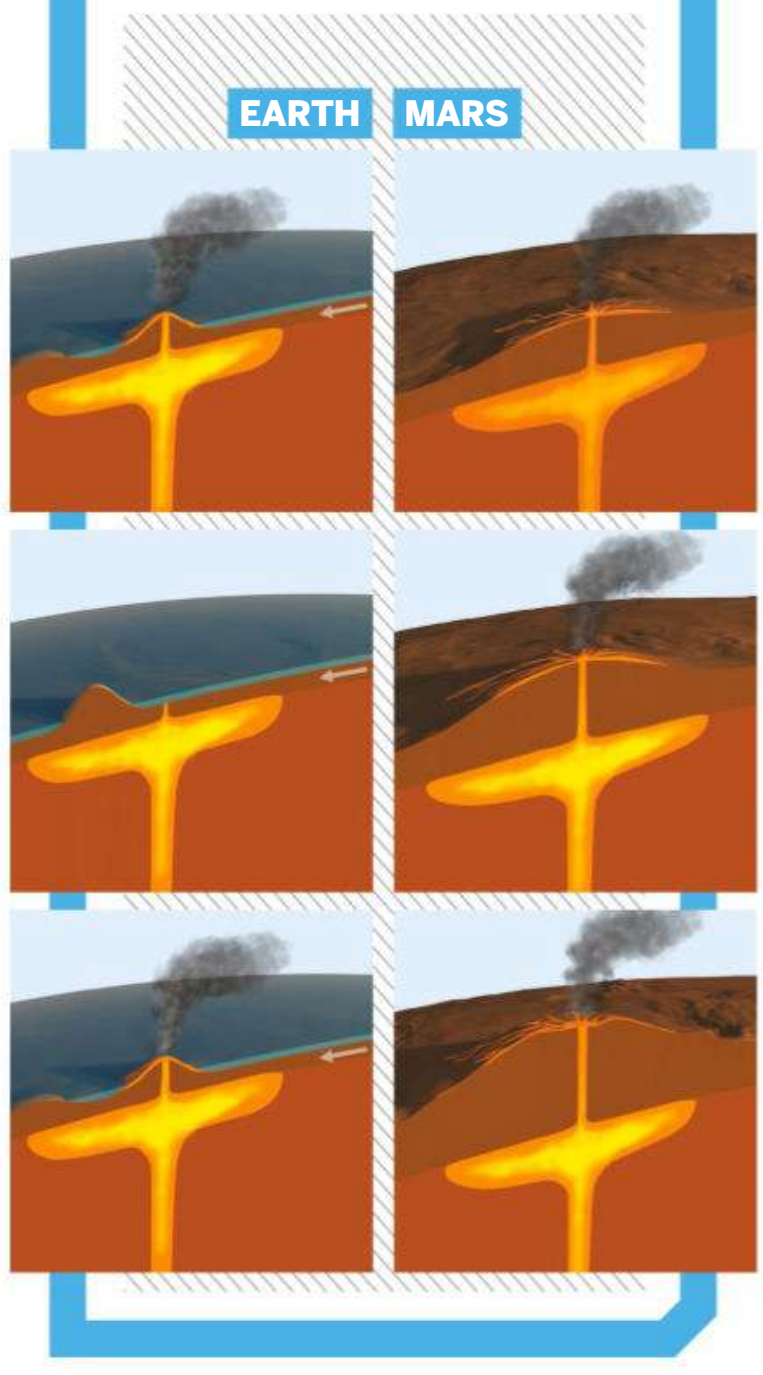
In Greek myth, Mount Olympus was home to the gods

The other important geological process that gives rise to mountains on Earth is volcanic activity. An active volcano is a vent or fissure on the planet's surface through which molten rock can erupt in the form of lava. Over time, the accumulation of solidified lava can result in a mountain being formed – this same process accounts for the formation of Martian volcanoes. On Earth, there are two main types of volcano: stratovolcanoes and shield volcanoes. The first kind are characterised by violent eruptions, steep sides and alternate layers – or strata – of lava and ash, from which they get their name. However, shield volcanoes have less violent eruptions, gently sloping sides and an unlayered structure composed of lava alone. The best known volcanoes on Earth, such as Vesuvius and Etna, with their dramatic and often deadly eruptions, are stratovolcanoes. But Mauna Loa in Hawaii is bigger than either of these – at 2.5 miles in height, it's the largest active volcano on Earth, and it's a shield volcano. The same is true of Olympus Mons on Mars.

Shield volcanoes get their name from their shape. If you picture a round shield laid flat on the ground, that's roughly how a shield volcano looks – very broad in proportion to its height at the centre. The reason the solidified lava takes this shape is that when it was molten it was very runny compared to the lava from a stratovolcano. As with Mauna Loa in Hawaii, this means the lava must have been very hot – around 1,200 Celsius – to make it sufficiently fluid. One unusual feature of Olympus Mons when compared to Martian terrain in general is that there aren't many impact craters on its surface. This indicates that the uppermost layer of lava is relatively young, with the last eruption occurring as recently as 25 million years ago. This raises the intriguing possibility that the volcano is still active, and may erupt again in the future.

WHY IS OLYMPUS MONS SO BIG?

In the past, when Mars retained much more internal heat than it does today, it was as volcanically active as our planet. The basic geological process behind volcano formation worked in much the same way as it does on Earth. In terrestrial volcanoes, molten rock, known as magma, is forced up through vents from the interior of the planet to the surface, where it emerges as lava. The big difference lies in what happens as this process progresses over time. On Earth, because the surface crust takes the form of slowly drifting tectonic plates, these plates move over the hotspot where the lava emerges. The result is a chain of separate volcanoes, as found in the Hawaiian Islands. But Mars doesn't have Earth-like tectonic plates, so the same bit of surface crust remains stationary over a hotspot. Successive eruptions simply make the original volcano bigger and bigger.



DID YOU KNOW? After ten years climbing up Mount Sharp, Curiosity is more than 600 metres higher than when it landed

TOPOGRAPHY OF A GIANT VOLCANO

A sprawling heap of solidified lava, Olympus Mons is really quite simple in structure

1 VIEW FROM ORBIT
This is a colour-coded mosaic of images captured by the Mars Express orbiter.

2 ESCARPMENT
The outer rim of the volcano is marked by a steep cliff over 4.3 miles high.

3 HIGHEST POINT
The volcano's summit, 16 miles above the surrounding plain, is on the rim of the caldera.

4 CALDERA
This is a depression at the centre about 1.9 miles deep.

5 CRATERS
There are relatively few impact craters on the volcano due to its comparatively young age.

HEIGHT CONTOURS
Blue represents the lowest elevation, and white the highest.

-5 KM 5 KM 17 KM 22 KM

N ↑ 120 km

This composite image shows the steep escarpment surrounding Olympus Mons

© NASA / ESA / Lunar and Planetary Institute / Illustration by Adrian Mann

MARS MOUNTAIN MISSIONS

Almost everything we know about Olympus Mons comes from space missions. Here are some of the most important

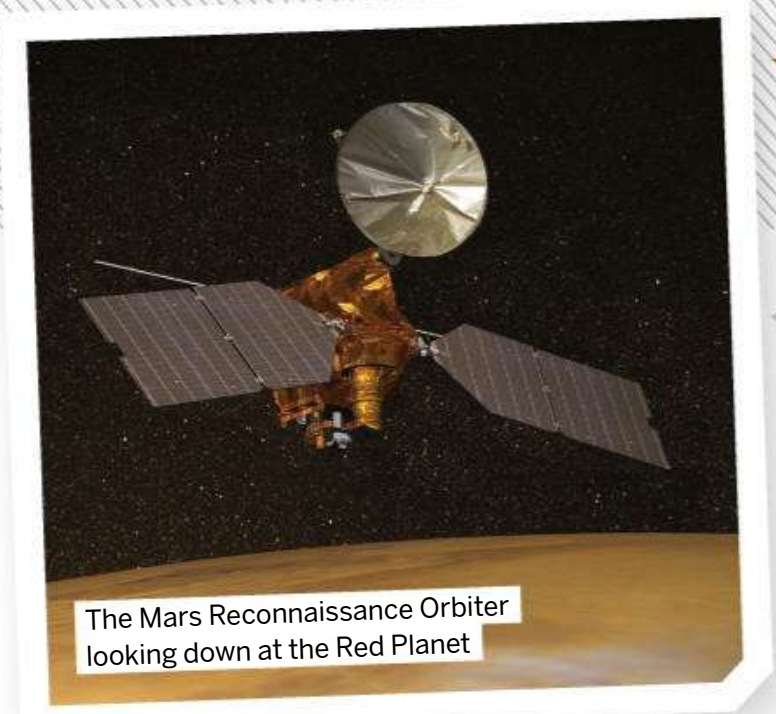
The first Mars orbiter, Mariner 9, was almost 7 metres across including its solar panels

MARINER 9

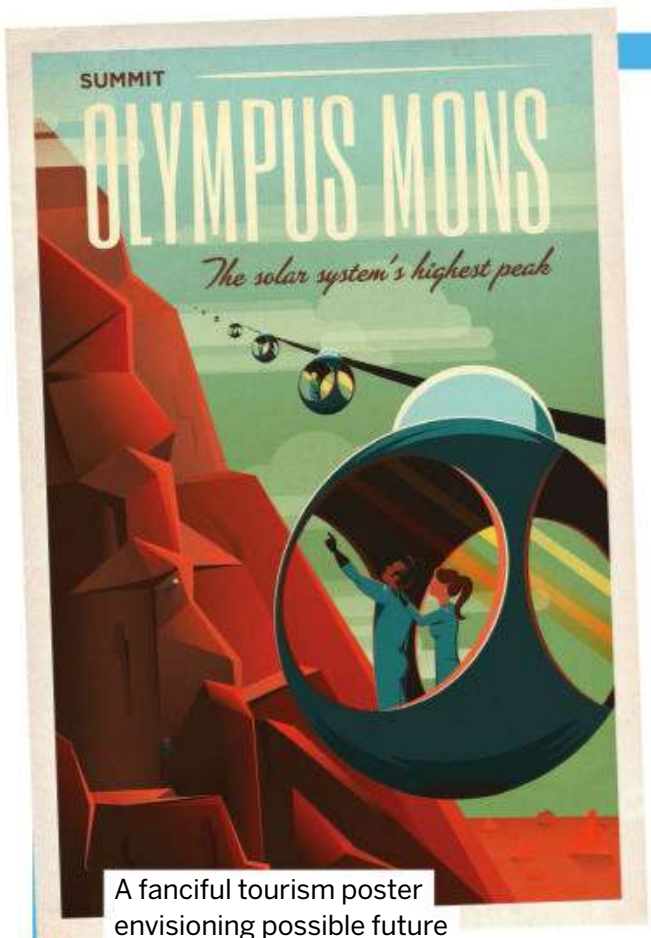
The novel feature of NASA's Mariner 9 probe was a rocket engine powerful enough to place it in a stable orbit, allowing it to observe the planet at leisure. The previous successful Mars missions – Mariners 4, 6 and 7 – had only involved fleeting flybys, collecting a meagre 222 images between them. Mariner 9's main objective was to photograph a large proportion of the Martian surface from close quarters over the course of several months. Unfortunately, when the spacecraft reached the Red Planet in November 1971, the entire planet was enshrouded in a global dust storm. This would have been a disaster for a flyby mission, but the orbiter was able to wait patiently for the dust to clear. When it did, it captured 7,329 images covering 80 per cent of the Martian surface, revealing a host of hitherto unknown features, including Olympus Mons and several other towering volcanoes.

CURRENT MARS ORBITERS

Since Mariner 9, numerous spacecraft have followed in its footsteps by going into orbit around Mars. These include NASA's Mars Odyssey and the European Space Agency's Mars Express, which arrived at the Red Planet as long ago as 2001 and 2003 respectively, yet are still operational today. Both have sent back spectacularly detailed images of Martian surface features, including Olympus Mons and other massive volcanoes. But even their performance pales beside that of NASA's Mars Reconnaissance Orbiter (MRO), launched in 2005, which carries the most powerful camera ever flown on a planetary exploration mission. While its predecessors could pick out details a few metres in size, MRO can resolve objects as small as a dinner plate, just centimetres across. Most recently, Hope – a spacecraft designed and operated by the United Arab Emirates (UAE) – entered orbit around Mars in February 2021. One of the first images it sent back showed Olympus Mons.



The Mars Reconnaissance Orbiter looking down at the Red Planet

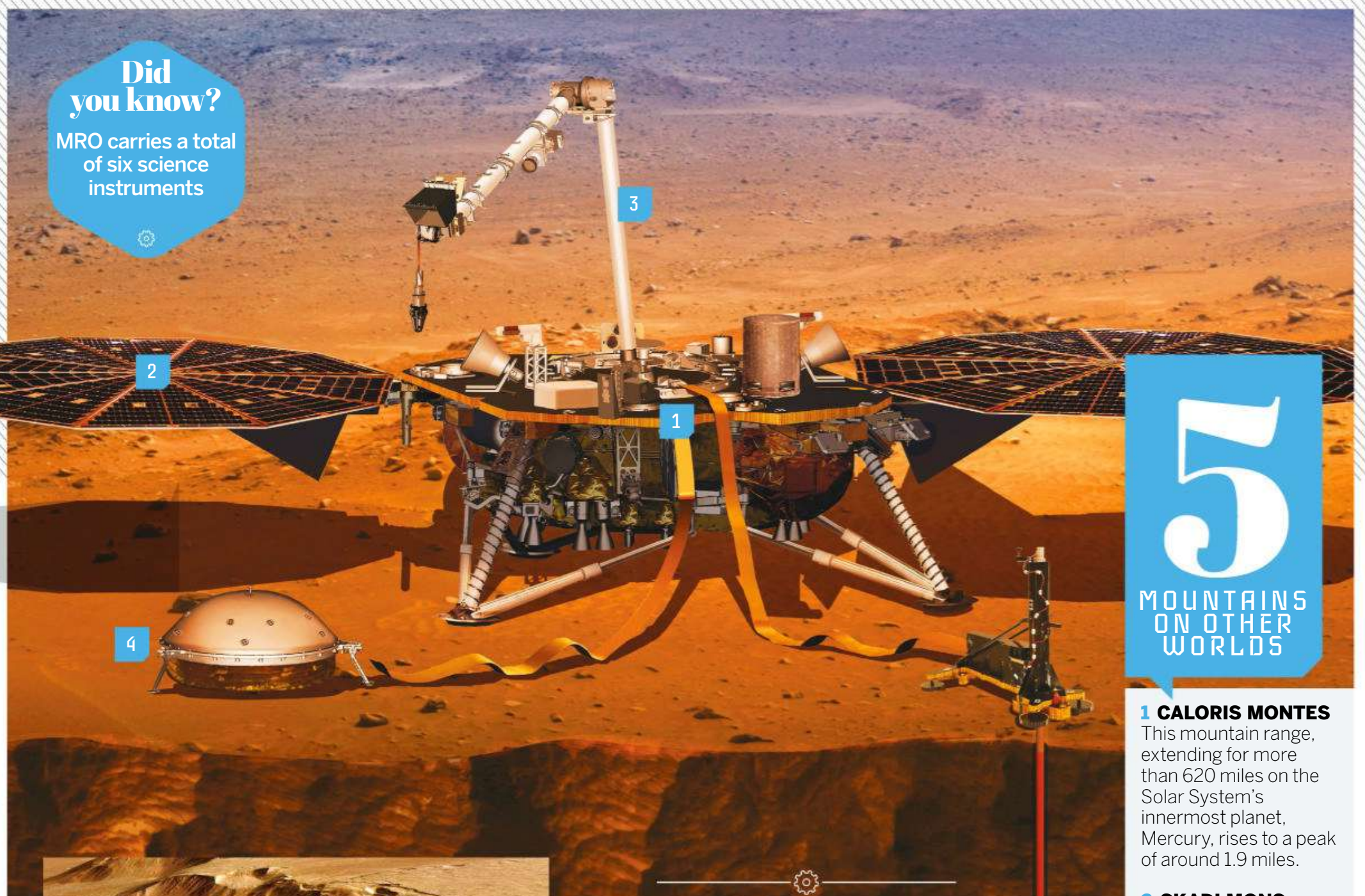


A fanciful tourism poster envisioning possible future excursions to Olympus Mons

LANDING ON OLYMPUS MONS?

To date, Olympus Mons has only been studied by orbiters from a distance; no surface rovers have been anywhere near it. Despite its obvious interest, it's not an easy landing site for a couple of reasons. The high altitude makes a parachute-assisted descent difficult in the tenuous atmosphere, while the presence of loose dust would cause manoeuvring problems for rovers. Even so, if Martian space tourism gets going in the coming decades, Olympus Mons could become a prime target for adventurous holiday-makers. In 2021, a group of students from the Royal Institute of Technology in Stockholm, Sweden, put together a proposal for a mission they believed might be feasible by 2042. A rover would take a group of three people close to the summit of the giant volcano, and then two of them would complete the final journey on foot.

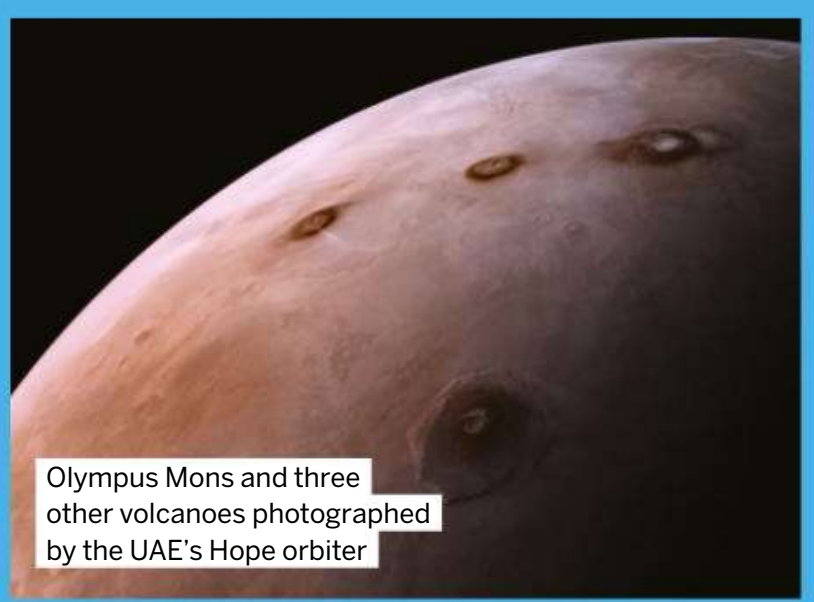
DID YOU KNOW? Mariner 9 was supposed to be one of a pair, but its twin, Mariner 8, failed shortly after launch



MARS INSIGHT

This small NASA lander, which operated between 2018 and 2022, was designed to study past and present seismic activity on Mars by probing its interior

A high-resolution view of part of Olympus Mons, as seen by Mars Express


Olympus Mons and three other volcanoes photographed by the UAE's Hope orbiter

1 LIGHTWEIGHT LANDER
InSight is much smaller than other recent Mars landers, with a mass of just 358 kilograms.

2 SOLAR PANELS
The lander's main source of power, these eventually became too dust-covered for the mission to continue.

3 INSTRUMENT DEPLOYMENT ARM
This 1.8-metre-long robotic arm was used to place the seismometer and other instruments on the Martian surface.

4 SEISMOMETER
One of InSight's most important instruments, this was designed to measure 'marsquakes' and any other subsurface activity.

5 HEAT-FLOW PROBE
This hammered its way five metres into the Martian crust to measure the subsurface temperature profile.

5 MOUNTAINS ON OTHER WORLDS

1 CALORIS MONTES
This mountain range, extending for more than 620 miles on the Solar System's innermost planet, Mercury, rises to a peak of around 1.9 miles.

2 SKADI MONS
With a height of 6.6 miles, this mountain in the Maxwell Montes range is the highest peak on Earth's closest planetary neighbour, Venus.

3 MONS HUYGENS
This is one you can see for yourself with a telescope. At 3.4 miles in height, it's the Moon's tallest mountain, on the edge of Mare Imbrium.

4 AHUNA MONS
Proving that even a small world can have a big mountain, this 2.5-mile-high peak is located on the dwarf planet Ceres in the asteroid belt.

5 TENZING MONTES
This icy mountain range can be found on another dwarf planet, Pluto, on the edge of the Solar System. Its highest point towers around 3.8 miles above the surroundings.

© NASA / ESA / UAE Space Agenc / SpaceX

NATURE'S CRAZIEST CANNIBALS

WORDS **SCOTT DUTFIELD**

From starvation to devouring an opponent, there are many reasons why an animal might feast on its own kind

DID YOU KNOW? The praying mantis evolved 146 to 66 million years ago

A wolfsnail attacking and eating a native snail

SNAILS UNLEASHED

The rosy wolfsnail (*Euglandina rosea*) is a pinkish terrestrial snail that can be found around the world, including the US, India, Japan, Madagascar and China. Using chemical receptors in their antennae-like lips, rosy wolfsnails can track other snails through their mucus trails. When a wolfsnail encounters another snail, it will quickly begin sucking at the shell opening, hoovering out the gelatinous snail within. Some wolfsnails don't even bother to navigate around the shell and devour the entire snail whole, shell and all. In 1995 they were introduced to the Hawaiian Islands by the Hawaii State Department of Agriculture to tackle the growing threat of giant African snails, another introduced species. Although the wolfsnails were adept at hunting giant African snails, they also had a taste for Hawaii's native snail species. The 21 species of Carelia snails, endemic to Hawaii's fourth-largest island Kauai, are now believed to be extinct.

Did you know?

The average garden snail has around 14,000 teeth

© Alamy / Getty

A female praying mantis eating a male after mating

LOVE AT FIRST BITE

The insect world is filled with weird and extraordinary mating behaviours, including sexual cannibalism. Female praying mantises, along with some species of spiders, devour their mates for an easy nutritional boost. Typically, this intraspecies dining occurs after the deed is done, but praying mantis females can be a little more impatient. During mating, a female mantis will turn her head to meet her partner's, tear it apart and eat it. Surprisingly, this act of cannibalism doesn't stop the mate from mating. In the process of losing his head, the female severs a nerve called the suboesophageal ganglion, which inhibits mating. With this nerve cut off, the rest of the male's body continues to mate long after decapitation.

However, not all males are up for losing their heads to have children. A study by the University of Auckland found that male mantises that won a wrestle with a female before mating lived to see another day. Sexual cannibalism isn't as common as many people believe and occurs less than 30 per cent of the time during the mantis mating season. Female springbok mantises (*Miomantis caffra*) appear to be more fond of eating their partners, doing so in around 60 per cent of encounters.

Did you know?

A praying mantis can turn its head 180 degrees

ANTENNAE
The two long antennae on a mantis' head are used for navigation, to seek out prey and to find a mate.

EYES
These insects have a pair of compound eyes that allow them to see far into the distance to locate prey.

MANDIBLES
Praying mantises have sharp jaws called mandibles that clamp down on and cut through their prey.

PRAYING ARMS
Although they look like arms, these are elongated legs equipped with spines to pierce and grip on the bodies of prey.

LEGS
A praying mantis has six legs in total, which are covered in tiny hairs for climbing.

WINGS
Not all mantis species are able to use their wings to fly. Some use them to glide from plant to plant, while others use them to attract a mate.

PRAYING MANTIS ANATOMY

The features that make these insects perfect predators

DID YOU KNOW? The king cobra is the longest venomous snake, growing to around six metres long

A female caecilian and her flesh-eating offspring

MORE THAN MOTHER'S MILK

There isn't much a mother wouldn't give her children, and for caecilians – worm-like amphibians – that includes their own flesh. Once a caecilian mother has laid her eggs she secretes a fatty, nutrient-rich layer of skin around her body. When the young, limbless amphibians hatch from their eggs, they begin to chow down on their mother's skin. Young caecilians are born with shovel-like teeth that can scrape away at each layer of skin that the mother produces for up to three months. Studies have shown that a caecilian mother will lose around one-seventh of her body weight during the feeding period, which researchers found in the stomachs of her young.

TOXIC MASCULINITY

Cobras are among the most venomous and dangerous snakes in the world, and studies have shown that they aren't even safe from each other. Researchers at the University of the Western Cape in South Africa have discovered that between 13 and 43 per cent of all prey species in diets of surveyed cobras were other snakes, including their own species.

The most cannibalistic of the snakes they surveyed were Cape cobras, which chose to eat other members of their own species for around four per cent of their meals. As to why cobras choose to eat each other, the answer might depend on their sex. In each of the cases of cannibalism that the researchers documented, both the devourer and the devouree were male. It's been suggested that for cobras, cannibalism is a possible method of removing sexual competition.

An Indian cobra feasting on another Indian cobra

The mother allows herself to be eaten by her young

SELF-SACRIFICE

The crab spider (*Australomisidia ergandros*) might just be one of the most selfless species on Earth. As mothers, these eight-legged arachnids not only protect their bundle of eggs while they develop into tiny spiderlings, but in the weeks after they hatch they become a food factory to help their young grow. Crab spiders lay sacks of unfertilised eggs for spiderlings to feast on, but a mother can only produce a certain number of sacks. When her young have eaten all the egg sacks, the mother will tap on the family web a few times and push herself into her brood, awakening the hunter behaviour of her spiderlings. They quickly swarm her body and begin devouring her. Over the course of weeks, she is eaten until there is little left behind.

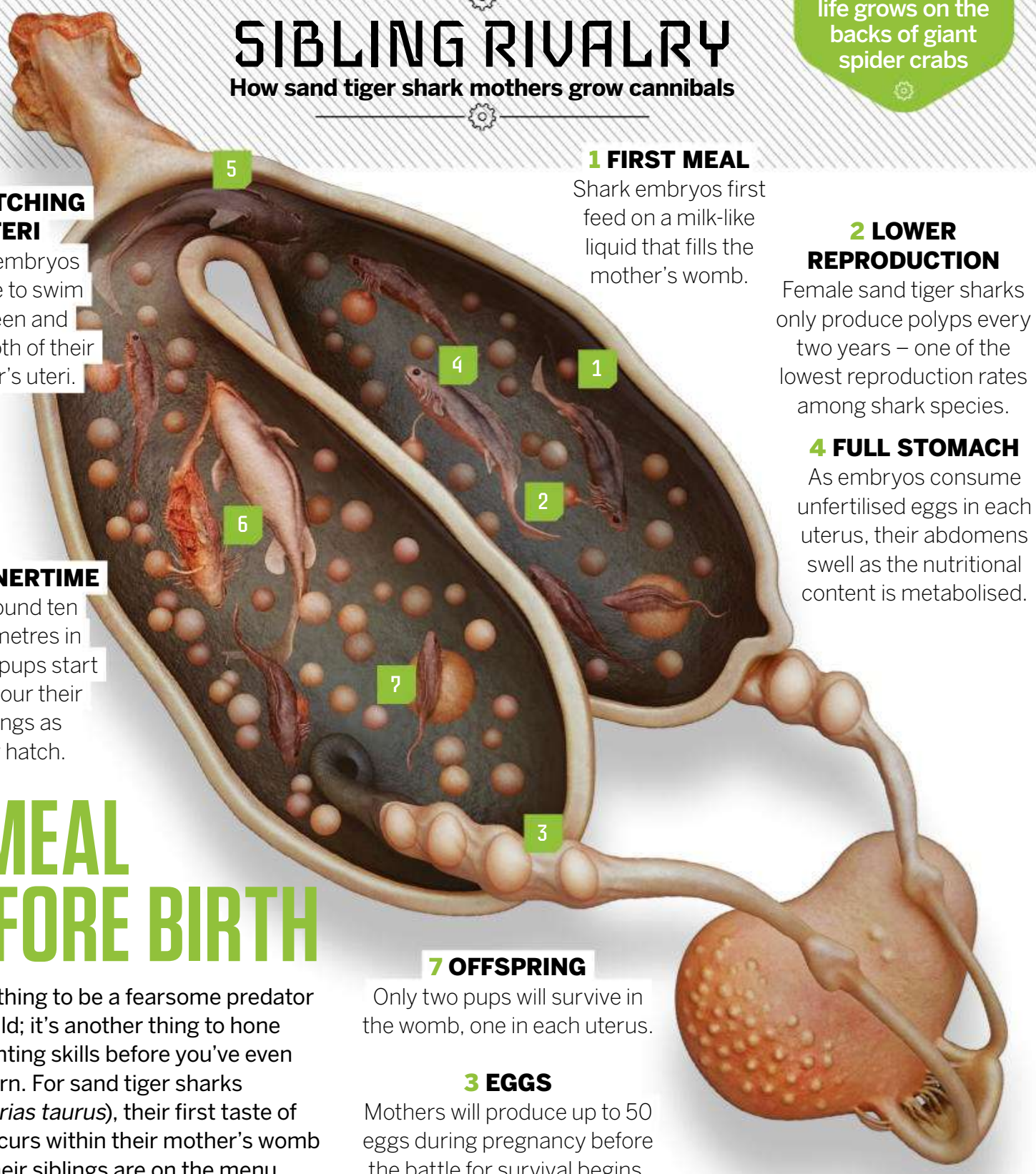
© Alamy / Getty

SIBLING RIVALRY

How sand tiger shark mothers grow cannibals

Did you know?

Seaweed and other life grows on the backs of giant spider crabs



5 SWITCHING UTERI
Shark embryos are able to swim between and utilise both of their mother's uteri.

1 FIRST MEAL
Shark embryos first feed on a milk-like liquid that fills the mother's womb.

2 LOWER REPRODUCTION
Female sand tiger sharks only produce polyps every two years – one of the lowest reproduction rates among shark species.

4 FULL STOMACH
As embryos consume unfertilised eggs in each uterus, their abdomens swell as the nutritional content is metabolised.

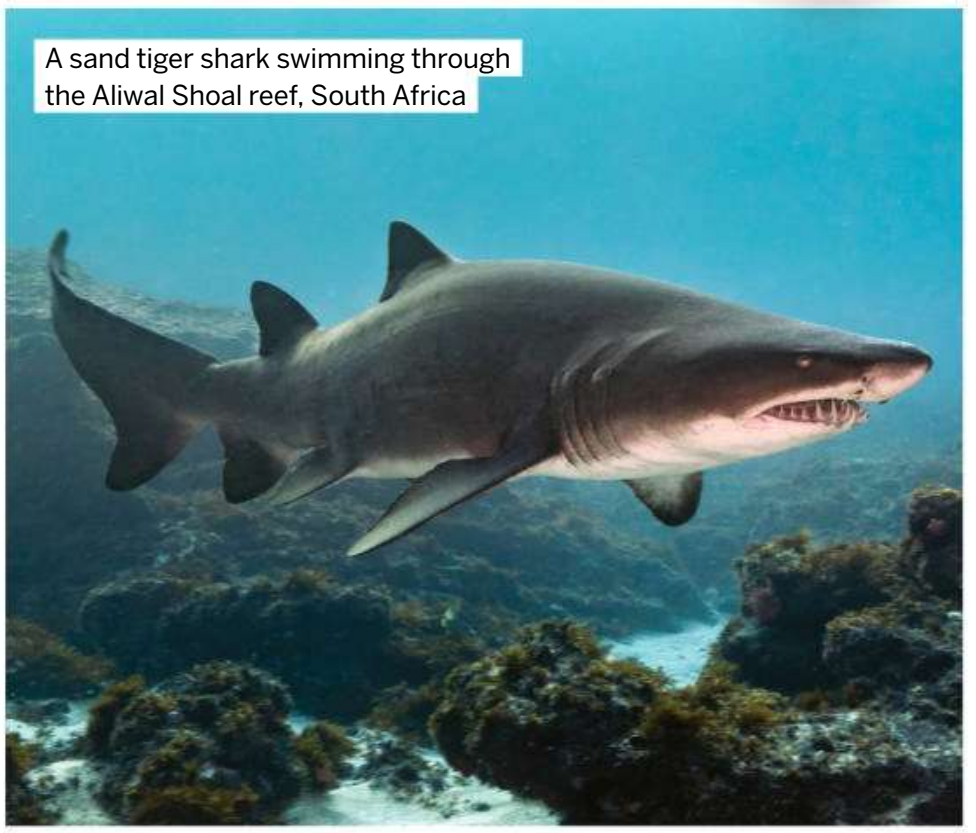
6 DINNERTIME
At around ten centimetres in length, pups start to devour their siblings as they hatch.

7 OFFSPRING
Only two pups will survive in the womb, one in each uterus.

3 EGGS
Mothers will produce up to 50 eggs during pregnancy before the battle for survival begins.

A MEAL BEFORE BIRTH

It's one thing to be a fearsome predator in the wild; it's another thing to hone your hunting skills before you've even been born. For sand tiger sharks (*Carcharias taurus*), their first taste of flesh occurs within their mother's womb – and their siblings are on the menu. During breeding season, a female sand tiger shark will typically produce a dozen or so encapsulated embryos across two uteri. One by one, shark hatchlings emerge from their capsules within either the right or left uterus. However, it's the first ones to hatch that get to survive. Once free from their capsules, the first hatchlings, typically around ten centimetres long, embark on a spree of devouring all the other shark embryos in each uterus until there are only two pups left. With their appetites not yet satisfied, the two triumphant shark pups will turn to unfertilised eggs for food. Sand tiger shark pups are born after a gestation period of between eight and nine months and emerge as sharks up to 105 metres in length. This juvenile form of cannibalism is known as intrauterine cannibalisation and occurs in several shark species.



A sand tiger shark swimming through the Aliwal Shoal reef, South Africa

5 CUTE CANNIBALS

1 RED SQUIRRELS
These fuzzy little tree-dwellers have been found to fight to the death. In seasons when food is scarce, they also eat each other.

2 RABBITS
A mother that's just given birth will instinctively eat her fresh offspring if she senses a predator nearby to prevent them from smelling the newborns' scent and discovering her.

3 CATS
Although it's very rare for cats to eat one another, during the pandemic, some of the 750 or so 'wild' cats on Ilha Furtado island in Brazil turned to one another for food.

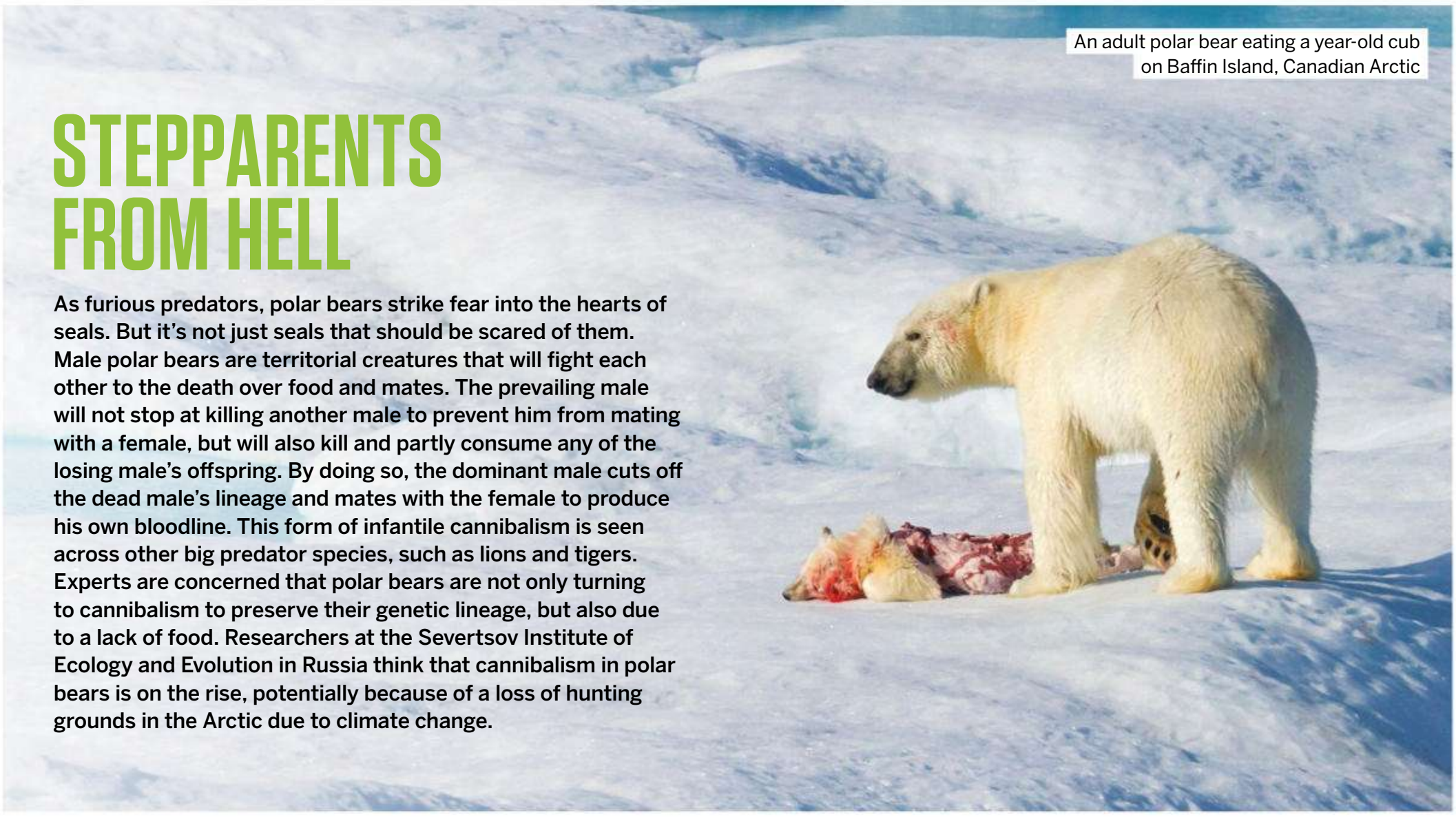
4 HEDGEHOGS
Hedgehog mothers have a similar reaction to rabbits and will eat their young when they are frightened or stressed.

5 DUCKLINGS
When ducklings over four weeks old are either bored, extremely hungry or overcrowded, they sometimes turn to cannibalism.

DID YOU KNOW? A polar bear can consume up to 68 kilograms of food in one sitting

STEPPARENTS FROM HELL

As furious predators, polar bears strike fear into the hearts of seals. But it's not just seals that should be scared of them. Male polar bears are territorial creatures that will fight each other to the death over food and mates. The prevailing male will not stop at killing another male to prevent him from mating with a female, but will also kill and partly consume any of the losing male's offspring. By doing so, the dominant male cuts off the dead male's lineage and mates with the female to produce his own bloodline. This form of infantile cannibalism is seen across other big predator species, such as lions and tigers. Experts are concerned that polar bears are not only turning to cannibalism to preserve their genetic lineage, but also due to a lack of food. Researchers at the Severtsov Institute of Ecology and Evolution in Russia think that cannibalism in polar bears is on the rise, potentially because of a loss of hunting grounds in the Arctic due to climate change.



An adult polar bear eating a year-old cub on Baffin Island, Canadian Arctic

IT'S A CRAB-EAT-CRAB WORLD

There aren't many crustaceans that enjoy the taste of their own kind. But for giant spider crabs during moulting season, the allure of soft and tasty crab meat is just too great. Once a year, the seafloor around Victoria, Australia, has a stampede of giant spider crabs (*Leptomithrax gaimardii*), gathered in their thousands to moult their hard exoskeletons. Around June, Port Phillip in southern Victoria is littered with the discarded shells of spider crabs that have outgrown their old skin. It's thought that these crustaceans gather together for a 'safety-in-numbers' approach to protection during this vulnerable part of their life cycle. Once the crabs have moulted and stepped out of their exoskeletons, the new exoskeleton that's been growing underneath is still soft – not yet hard enough to protect them from hungry predators. In a couple of days the new exoskeleton hardens and the crabs resume their typically solitary lives.

Giant spider crabs marching in their thousands on the seafloor

Putting too many chickens in a coop may cause them to eat each other

CLUCKING CANNIBALS

It might be hard to imagine chickens as cannibals, but under certain conditions they can quickly turn on each other. The act of eating one another is not a natural behaviour for chickens. However, when these birds are stressed or poorly managed they begin to peck at their own kind. When a bird has been pecked enough that a bleeding wound forms, then more chickens will descend on the wounded. Overcrowding, a lack of food, mixed flocks and slow-feathering chickens can all lead to chicken cannibalism. Also, the inner lining or 'mucosa' of a chicken's vent, which is the opening where eggs fall out, can protrude during egg-laying. The red-coloured tissue can lead to chickens pecking at it.

© Alamy / Getty / Illustration by Nicholas Forder

WHERE DOES TOBACCO COME FROM?

Tobacco farmers collecting leaves to cure in Cuba

Often found packed tightly into cigarette paper, this dry and woody product is unrecognisable from its natural form

WORDS **AILSA HARVEY**

Tobacco has been harvested and used by humans for at least 8,000 years across North and South America. However, the link between tobacco exposure and declining health wasn't recorded until the beginning of the 1600s, when the then-theory was written by an anonymous author. Initially, tobacco was used as a method to improve health. Tobacco is a flowering plant, and was used 2,000 years ago as part of religious ceremonies and in medicinal practices due to its antibacterial properties. This included wrapping the plant around wounds and chewing on the leaves to relieve toothache. Soon after, people discovered that the tobacco leaves could be burned and inhaled as a faster acting stimulant. Smoking, as it is commonly known as today, was quick to gain popularity. Tobacco was easy to access and people were completely unaware of the damaging impacts that inhaling the smoke had on the body, such as lung damage and an increased risk of cancer. It wasn't until the early 1960s that hard evidence of tobacco's detrimental health effects was published.

Today, tobacco is grown and available to purchase in many countries, but some farmers have replaced tobacco crops with alternative plants as the detrimental effects smoking has on human health are more widely understood. Farmers who work on tobacco farms absorb volumes of nicotine equivalent to 50 cigarettes a day. Because nicotine is soluble in fats, farmers who handle tobacco leaves extensively can absorb nicotine through their skin. Even though the market for it has reduced considerably, around 1.3 billion people still use tobacco, with 6.7 million tonnes being produced every year.

Tobacco leaves hanging to dry

Did you know?

In 1828, two chemistry students extracted nicotine from tobacco

FROM PLANT TO CONSUMER

Follow the steps that turn this plant into an addictive and harmful product

Tobacco plants are planted in rows when moved into fields

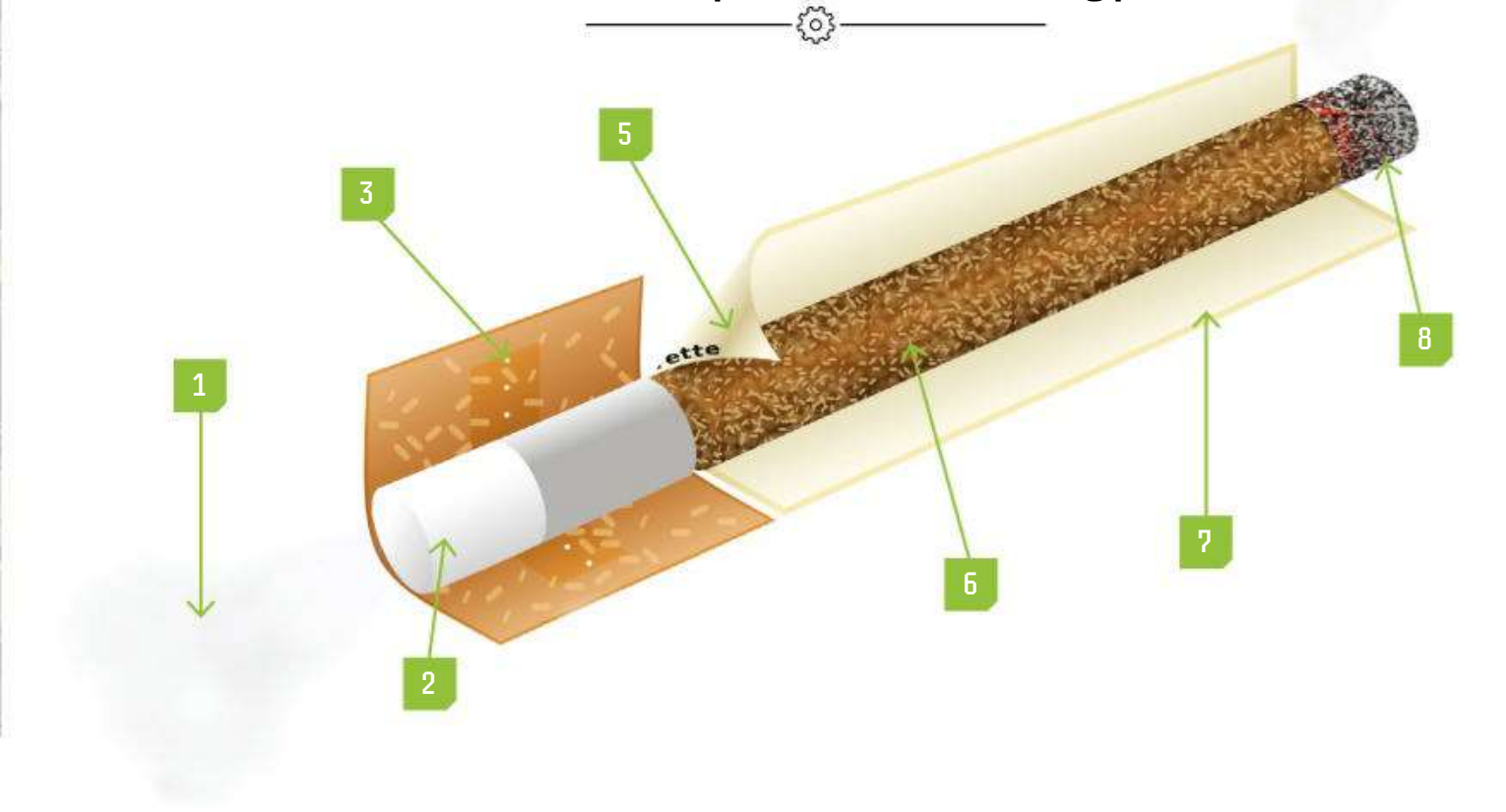
1 PERFECT GROWTH

It takes about two months for a seed to grow into a 20-centimetre tobacco plant. There are tobacco farms in over 30 countries, including Brazil, Mozambique, Spain and the US. The tobacco plants are then transplanted into fields to grow for a further 90 to 120 days.

DID YOU KNOW? In 2020, 36.7 per cent of men and 7.8 per cent of women used tobacco

INSIDE A CIGARETTE

How tobacco is incorporated into this smoking product



1 SMOKE
The smoke inhaled from burning tobacco includes more than 5,000 chemicals. These include harmful nicotine, carbon monoxide and acrolein.

2 FILTRATION
This filter blocks the larger particles of tar from entering the mouth and lungs. This is a product of burnt tobacco matter.

3 VENTILATION
Air is drawn in through these holes when a smoker inhales. This provides the tobacco and smoke with a milder taste.

4 SIDESTREAM SMOKE
The tobacco is lit from the end furthest from the mouth. As it burns, smoke is released.

5 TIPPING PAPER
This is the part a smoker's mouth touches. Sweeteners and flavourings are often added to this strong paper.

6 TOBACCO
The tobacco fills most of the space in a cigarette. Typically, one cigarette weighs one gram, with its tobacco content weighing 0.8 grams.

7 PAPER
Cigarette paper is made from light plant fibres. The number of pores in cigarette papers vary to match tobacco types and flavours.

8 BURNING POINT
Burning tobacco changes its chemical composition, releasing harmful chemicals.

A NATURAL PLANT

Tobacco grows as leaves from the thick, hairy stem of the tobacco plant (*Nicotiana tabacum*). These leaves are harvested for making cigarettes, while tobacco plants also produce white, red and pink flowers. The plant is native to South America, but it's now grown all around the world due to the demand for its large, oval-shaped leaves. Tobacco leaves contain an organic compound called nicotine, which is an addictive stimulant when absorbed by the human body. The nicotine speeds up chemical signals between the brain and body. One of the most common ways people consume this drug is by burning the cured and shredded leaves of tobacco plants and inhaling the smoke. However, nicotine addiction can cause an increase in heart rate, blood pressure and a narrowing of arteries – this alone can increase the risk of a heart attack or stroke.

Tobacco plants' leaves grow up to about 50 centimetres long

As tobacco leaves dry, they turn yellow

2 CUT AND CURE
The leaves are harvested from the plants when ripe. In other cases, part of the stem is also cut off the plant, and the plant is allowed to wilt slightly before curing. Curing is the process of drying the plant over a few weeks by hanging it in the air.

Wood is often used as a fuel to heat tobacco-curing barns

3 ALTERNATIVE CURING
Curing barns can be used to cure tobacco in a slightly different process known as flue-curing. This involves raising the temperature of the barns slowly up to 79 degrees Celsius to dry the leaves. A chimney, or flue, releases the smoke produced during barn heating.

Grading gives tobacco an even colouring

4 STRIPPING AND GRADING
The leaves are moistened so that they can be stripped without them breaking apart. This is to separate any stalks that are still attached to the cured leaves. The leaves are then graded based on their colour and size.

Tobacco can be seen packed tightly into cigarettes

5 CIGARETTE PACKING
In a factory, the leaves are shredded, and some menthol may be added for flavour. The tobacco is spread evenly over cigarette papers before machines roll them into cylinders and package 20 cigarettes into each carton.

© Alamy / Getty / Semhur/ Wikimedia CommonsSemhur

HOW ROBOTIC LIMBS CHANGE LIVES

Discover the body-enhancing bionics that can give humans and animals a new lease of life

WORDS: AILSA HARVEY

DID YOU KNOW? Typically, robotic arms have seven segments and six joints

While some robots are intended to assist humans, robotics can also reproduce realistic limb-like functions for those that have lost arms, legs and other parts of their bodies. These prosthetics have existed in one form or another since at least ancient Egyptian times. Early limb replacements involved using materials such as wood or leather for support and balance. In the 1960s, the capabilities of prosthetics to enhance lives were explored. This included incorporating lightweight carbon-fibre material into prosthetics so that amputees could partake and succeed in sporting activities.

However, it wasn't until 1986 that electronic prosthetic limbs were explored. Scottish inventor David Gow began his mission to make existing pneumatic arms easier to use, lighter in weight and more functional. This led to the first bionic arm being ready for use in 1998. The first user of this bionic arm was a man named Campbell Aird, who lost his arm to cancer. After experiencing the benefits of an electrically powered, lightweight limb, Aird said at the time: "For the first time in 16 years I recently reached above my head to pick a book off a shelf. It was a great moment for me."

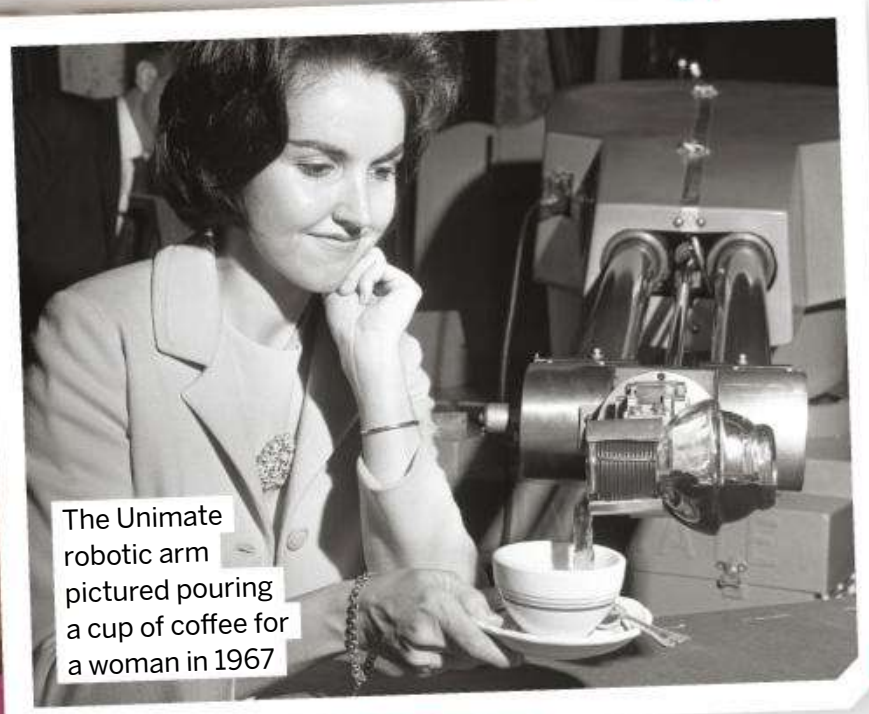
Today, the pioneering work in robotics is allowing those who are missing a limb to explore the world with better balance, accuracy, precision, speed and in some cases even touch. A new competitive event called the Cybathlon has been established to compare the speed, skills and efficiency of robotic limbs. The 'arm prosthesis race' is designed to rank new robotic arms in sensory feedback, palm rotation ability and coordination in handling objects of different sizes, shapes and weights. 20 countries partake in this event, further driving the innovation of life-changing technology.

Did you know?

'Prosthetic' is a Greek word meaning 'addition'

BIONIC BEGINNINGS

American inventor and entrepreneur Joseph Engelberger is widely known as the 'father of robotics' due to his part in producing the first robotic arm that could perform tasks too dangerous for humans. Engelberger was the face of the robotic arm, as he was the one who sold the concept of robotics in industrial settings. However, the first robotic arm was a joint effort alongside fellow American inventor George Devol, who was awarded the patent for the robotic arm and the technology behind it. This robotic arm was made in 1959, and the duo named it the Unimate #001. It was installed in factories that carried out die-casting – a process that involves handling hot metal and pouring it into different mould shapes. Before teaming up with Engelberger, Devol had named the invention the Programmed Article Transfer. Engelberger then used his passion for science fiction to find the best market and make the product exciting. He did this by being the first person to bring robotic arms into factories and helping people envision a future with robotics. While Devol mainly focused on the practical elements, Engelberger described an efficient robot takeover in the manufacturing industry.



The Unimate robotic arm pictured pouring a cup of coffee for a woman in 1967

5 WAYS WE USE ROBOTIC ARMS

1 FACTORY EFFICIENCY
Using robotic arms on factory lines makes manufacturing more reliable and timely. They also remove the chance of injury when handling dangerous materials.

2 LIMBS IN SPACE
The International Space Station (ISS) has three robotic arms on board. These can be controlled from inside the station to install, remove and replace ISS parts, as well as to conduct science experiments.

3 AUTOMOTIVE WORKERS
Robotic arms are used to weld metal together in automotive factories as well as for applying consistent coats of paint, cutting material and thoroughly polishing items.

4 AGRICULTURE
There are many repetitive and strenuous tasks required for a farm to run efficiently. This includes picking and packing crops and planting seeds. Some robotic arms have built-in sensors, helping them accurately carry out these roles.

5 LABORATORY HELPERS
Many experiments and processes are carried out in large batches. To make test tube dispensing, labelling and capping quicker, robots can be used to make dispensing accurate and reduce human error.

© Getty / WikiCommons: Frank Q. Brown murderers

SOLDIER ASSISTANCE

Soldiers need to be fit enough to carry heavy loads while also covering large areas of the battlefield. But thanks to robotic exoskeletons, troops are able to carry more than ever before. Combining body strength and mechanical strength, the FORTIS Knee Stress Release Device, developed by Lockheed Martin, is worn around the outside of the soldier's legs. In-built sensors detect the weight of the load they are carrying and the movement of the soldier to determine when they need assistance. This mostly includes squatting, kneeling and dragging objects. When the device detects these movements, the motorised knees are put into action to assist with the physical demands. This assistance means that soldiers need to use less physical energy to carry or pull objects, making lighter work of the activity and putting less strain on them. Depending on how the device is used, the exoskeleton can improve work rates between 2 and 27 times, making life easier for soldiers and reducing the likelihood of injury while performing tasks.

EXOSKELETON POWER

How the FORTIS Knee Stress Release Device works

2
1
3
1 AT THE WAIST
The top of the device is worn like a belt around the hips, providing upper-body support.
2 BATTERY POWER
The device is battery powered, but requires low energy. This means that batteries are small, helping keep the equipment relatively light.
3 SENSORS
The leg support panel has integrated sensors connected to the belt. These measure the weight being carried.

Did you know?

Over 2 million people are missing at least one limb

ADOPTING A THIRD THUMB

Humans have two opposable thumbs. These help us hold, grip and manipulate objects. If someone is born without a thumb, or loses one, thumb prosthetics can be strapped onto their hand to aid them. These need to be mechanical so that they can bend and lock in place, usually requiring the wearer to apply subtle pressure with the part of their natural hand in contact with the device. The invention of thumb prosthetics has also enabled scientists to experiment with the brain's interpretation of robotic limbs. In one experiment, researchers trained people to use prosthetic thumbs, even though they already had two natural thumbs – they had an extra thumb sticking out from the side of one hand.

By training their bodies to use their new thumbs, their brains began to associate the third thumb with their body, even beginning to believe that it was part of them. This research shows how technology can impact the brain, both allowing lost body functions to return and increasing the capabilities of natural anatomy – for example to carry more items at a time.

This shows how the thumb was attached

PET PROSTHETICS

Robotics aren't just used to emulate the movements of human limbs – animals are becoming bionic too. Technologically advanced prosthetics are becoming increasingly popular for pets and rescue animals. Four-legged animals such as dogs and cats balance easier than humans after losing a leg. However, these animals can still benefit from receiving a prosthetic replacement, as this can reestablish weight distribution. Without this, animals will overuse other parts of their body to compensate, causing other long-term injuries and reducing life expectancy.

At Auckland University of Technology, scientists used robotics to work out the best shape for a turtle fin prosthetic. This enabled them to return turtles that had been injured by natural causes, as well as fishing nets, to the water. To make manufacturing easier, the scientists tested different fin shapes on a robotic turtle. The results showed unanimously that the hydrofoil shape (a curved top) of a turtle's natural fins gave the animal the best swimming ability.

Prosthetics with a rounded end help dogs walk and run on four legs again

CAN YOU FEEL WITH A BIONIC ARM?

As robotic arms become more advanced, brain signals and technology can work together

LAB-GROWN NERVES
Stem cells can be manipulated in laboratories to grow nerves. These are used like a bridge to connect the body's nerves to the bionic arm.

SEVERED NERVE
The end of the cut nerve needs to be pulled apart slightly to stretch the long segment of the nerve cell, called the axon.

SIGNAL GENERATION
Sequences of brain neuron activity are generated to trigger a specific movement in the body.

MICROFILAMENT
An electrically conductive filament receives the electrical signals from the nerves and transfers them to the corresponding areas of the arm.

NERVE TRANSMISSION
Electrical signals travel through nerve cells, called neurons, towards the muscles that need to move.

RETURN SIGNAL
Just as nerve signals can be transferred to the arm, electrical signals in the bionic arm can be received by the nerves.

TOUCH SENSATION
Electrical signals triggered by contact of the bionic arm with an object can be redirected to the user's remaining skin and muscle cells to create the sensation of touch.

BIONIC ARM
The bionic arm can translate the nerve cell signals into mechanical movement.

© Getty / Dani Clode / Lockheed Martin / Illustration by Nicholas Forder

IPHONE 13 PRO TEARDOWN

How It Works explores the tech behind this smartphone's three artistic eyes

WORDS **AILSA HARVEY**

The iPhone 13 Pro comes in Gold, Silver, Sierra Blue, Graphite and Alpine Green

Many people take their phones with them wherever they go. Phones help them communicate, navigate, research and capture their surroundings at the touch of a button. The iPhone 13 Pro, which was released in September 2021, can do all of these things, but with a heavy focus on the latter. It takes very realistic snapshots, improving on any iPhone to have come before it. With its three versatile cameras, its 3x optical zoom allows users to record more distant objects, while the ultra-wide lens packs more action into every shot.

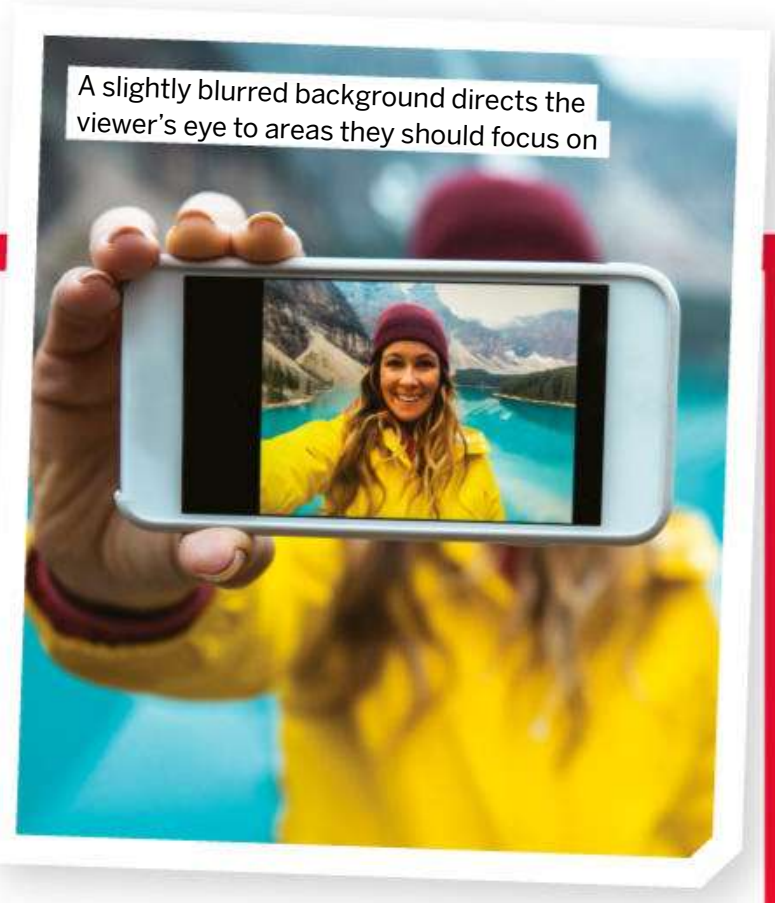
The phone has enhanced hardware and software to accommodate a wide range of conditions that photographs are taken in. This includes optimised night-vision cameras, drawing more light into the lens to brighten dark images, and new smart HDR 4 technology. HDR stands for high dynamic range, and is used to determine the exposure of a photograph.

This feature becomes useful when attempting to make photographs with contrasting exposures. For example, if your subject is standing with a bright light behind them, many phones display a silhouetted figure or have an overexposed background. When trying to edit the background to lower its exposure, the subject becomes too dark, while brightening the foreground results in the background turning bright white and losing its features. HDR 4 takes a combination of photos at the same time, all with different exposure levels. The resulting image combines multiple exposures to capture images with better clarity.

Did you know?

More than 40 million iPhone 13s sold in December 2021

Another improvement to this model when compared with previous iPhone Pro models is found in the screen's technology: this smartphone has a fast, 120 Hertz display. This means that the screen is able to refresh its display 120 times a second for smoother apps and video playback.


A slightly blurred background directs the viewer's eye to areas they should focus on

NEW CINEMATIC MODE

What sets the Pro models apart from standard iPhones is their camera quality. With an additional telephoto camera and higher optical zoom, the Pro model is for users who enjoy photography. One of the features of the iPhone 13 Pro that wasn't available in other Pro models is the new cinematic filming mode. With facial recognition technology and item detection, the phone analyses objects in the foreground and background. When someone or something enters the screen in the foreground, the depth-of-field effect works to slightly blur the background and focus on the foreground automatically. One of the more advanced features of the iPhone 13 Pro is that changes to the depth effect can be made after recording. After selecting the video in the photo gallery, you can edit which elements in the shot are in focus or blurred. For models before the 13 Pro, this element of the video's appearance is set as soon as the footage is produced.

8 TRIPLE LENS
The iPhone 13 Pro's three cameras are the wide-angle, ultra-wide-angle and telephoto cameras. The telephoto lens better captures details of more distant objects.

6 FRONT-FACING CAMERA
Above the phone's screen is a 12-megapixel front-facing camera.

The iPhone 13 Pro Max is similar to the iPhone 13 Pro, but is 0.6 inches bigger

DID YOU KNOW? The iPhone 13 Pro can survive being submerged at a depth of six metres for up to 30 minutes

3 LIDAR MODULE
The light detection and ranging (lidar) sensor emits lasers to measure how far away objects that are in front of the camera are. This can be used to measure objects' dimensions with the phone camera.

4 LAYERED LOGIC BOARD
This board contains the central processing unit (CPU) and other controls such as Bluetooth and Wi-Fi. It's responsible for most of the phone's operation.

BEHIND THE LENSES
The iPhone 13 Pro has three lenses, upgraded screen strength and much more under the hood

5 EARPIECE SPEAKER
This speaker slots in between the front-facing camera and the facial-recognition technology.

7 SIM CARD TRAY
The iPhone 13 Pro can hold a nano SIM card.

2 TAPTIC ENGINE
The iPhone 13 Pro has a much smaller Taptic Engine compared to the iPhone 12. This component is responsible for producing the phone's vibrations.

1 LARGE BATTERY
To improve battery life, the iPhone 13 Pro has an L-shaped battery. It is shaped so that it can fill up more free space in the phone, increasing its size and therefore increasing its energy-storing capacity.

© iFixit / Alamy / Getty

THE BIRTH OF THE JET FIGHTER

Jet fighters are the masters of modern aerial combat, but in the early years their dominance was far from inevitable

WORDS **STUART HADAWAY**

DID YOU KNOW? A Grumman F-11 Tiger once got shot as it was faster than its own bullet

In July 1944, the world's first two jet fighters began operational service. The Nazis' Messerschmitt Me 262 was being flown by an evaluation unit, as it had been for several months, but the skies over Germany were a dangerous place, full of Allied aircraft. On 26 July 1944, test pilot Lieutenant Alfred Schreiber engaged a Royal Air Force (RAF) de Havilland Mosquito reconnaissance aircraft. Over the following weeks, the type would see increasing action even while still under development, with the first front-line unit, Kommando Nowotny, being formed in October 1944.

In July 1944 the RAF re-equipped No. 616 Squadron with the Gloster Meteor. Restricted to operations over the UK, the type was soon in use against German V-1 rockets over southern England. Only in January 1945 would they be tentatively sent to the European continent, but forbidden from crossing the front lines until that April. They would claim nearly 50 enemy aircraft by the end of World War II, but all of them on the ground during attacks on airfields. The Me 262, meanwhile, would claim over ten times as many victories in air-to-air combat.

The types of engines used by both sides were turbojets, where air was sucked into compressors, heated in a combustion chamber, where fuel was added, and then expanded through a turbine and out the back of the engine. Ideas for other types of jet engines had been experimented with for decades, but it was RAF officer Frank Whittle who first produced a

©Getty

workable engine. Whittle had drawn up his first designs in 1928 and patented them in 1930. He presented his ideas to the RAF, but they showed little interest in the idea. After all, in 1930 the RAF was using biplanes made out of wood and fabric, and airframes that could withstand the strain of a jet engine were a dim and distant dream. However, Whittle was allowed to pursue his idea, and in 1937 he built his first working model. A specification was then issued for a jet fighter-type aircraft, and the Gloster E.28/39 duly first flew in 1941.

By then Whittle had been overtaken by German Hans von Ohain, who had produced his own turbojet plans, benefiting from Whittle's patent, in 1933. His first working model also ran in 1937, five months after Whittle's, but official interest in the project then accelerated progress. In August 1939 the Heinkel He 178 became the world's first aircraft to fly under turbojet power alone. Both countries were now working towards producing a practical jet warplane.

Although both were designed at the same time as twin-engined jet fighters, intended for use as fighters and for ground attacks, the Meteor and the Me 262 were very different aircraft. These differences in many ways typified the radically different approaches taken by the British – and by extension the other Allies – and the Germans in developing jet fighters.

The Germans were losing World War II on all fronts by the time the Me 262 became operational and were desperate for a secret weapon that would cause a leap to put them so far ahead of the Allies that the course of the conflict would swing irreversibly back in their favour. Driven by a leadership obsessed with exotic technology, already scarce resources were poured into rockets, rocket-engined fighters and jet aircraft.

The late-war Germans are famous for their wide range of futuristic aircraft designs, even if the majority of these were beyond the technical boundaries of the time. Their approach was highly mathematical, based on extensive calculations and applications of theoretical science, but the country lacked the raw materials, manufacturing capacity and time to produce such aircraft. The Me 262 was at the more practical end of the spectrum of designs. The type looked futuristic, with a streamlined fuselage and swept back wings – due to balance issues; it was nowhere near fast enough for aerodynamics to require them – but there were still flaws. The poor quality of the materials used in the Junkers Jumo 004 engines led to a practical life of as little as ten hours flight time.

On the other hand, the Meteor's design was much more traditional. The fuselage was highly conventional, as were the straight wings. The type was about 120 miles per hour slower than the Me 262, but its engines were far more reliable. Crucially, the Allies weren't looking for a miraculous war-winning weapon. They knew that success depended on manufacturing large numbers of proven existing piston-engined types, with incremental improvements where necessary, to the extent that the Gloster Aircraft Company was chosen to develop the first jet fighters specifically because the company wasn't developing any current frontline types.

The Americans took a similar approach, entrusting jet fighter development to the Bell Aircraft Corporation, and went a step further in applying the same principle to engine design. While the British used their most experienced engine manufacturer, Rolls-Royce – albeit based on Frank Whittle's designs – the Americans gave the engine designs

Air Commodore Sir Frank Whittle, inventor of the turbojet engine

provided by the British government in 1941 to General Electric, a company that had no aircraft engine experience, so as not to detract from mainstream production.

The Allies could and did take the longer view. Jet fighters were not needed to win World War II, and they could take their time to develop reliable and effective aircraft, and the related engines and fuel, at a slower pace. Their eyes were on the future, and in particular for Britain, the potential for post-war sales to help boost its shattered economy. In the months and years

Whittle's Power Jets W.1 engine, used in the Gloster E.28/39 and as the basis for the Rolls-Royce Welland and General Electric's J-series engines

INSIDE THE GLOSTER METEOR FR.9

A later iteration of the first British jet fighter

1 NOSE SECTION

The only major design change in the FR.9 iteration was the camera compartment, with multiple windows for aiming the equipment.

2 CRAMPED COCKPIT

The cockpit of the Meteor was cramped and crowded. Ejecting could be hazardous, with the risk of cuts or even broken bones.

DID YOU KNOW? A McDonnell Douglas F-15 Eagle once shot down a satellite

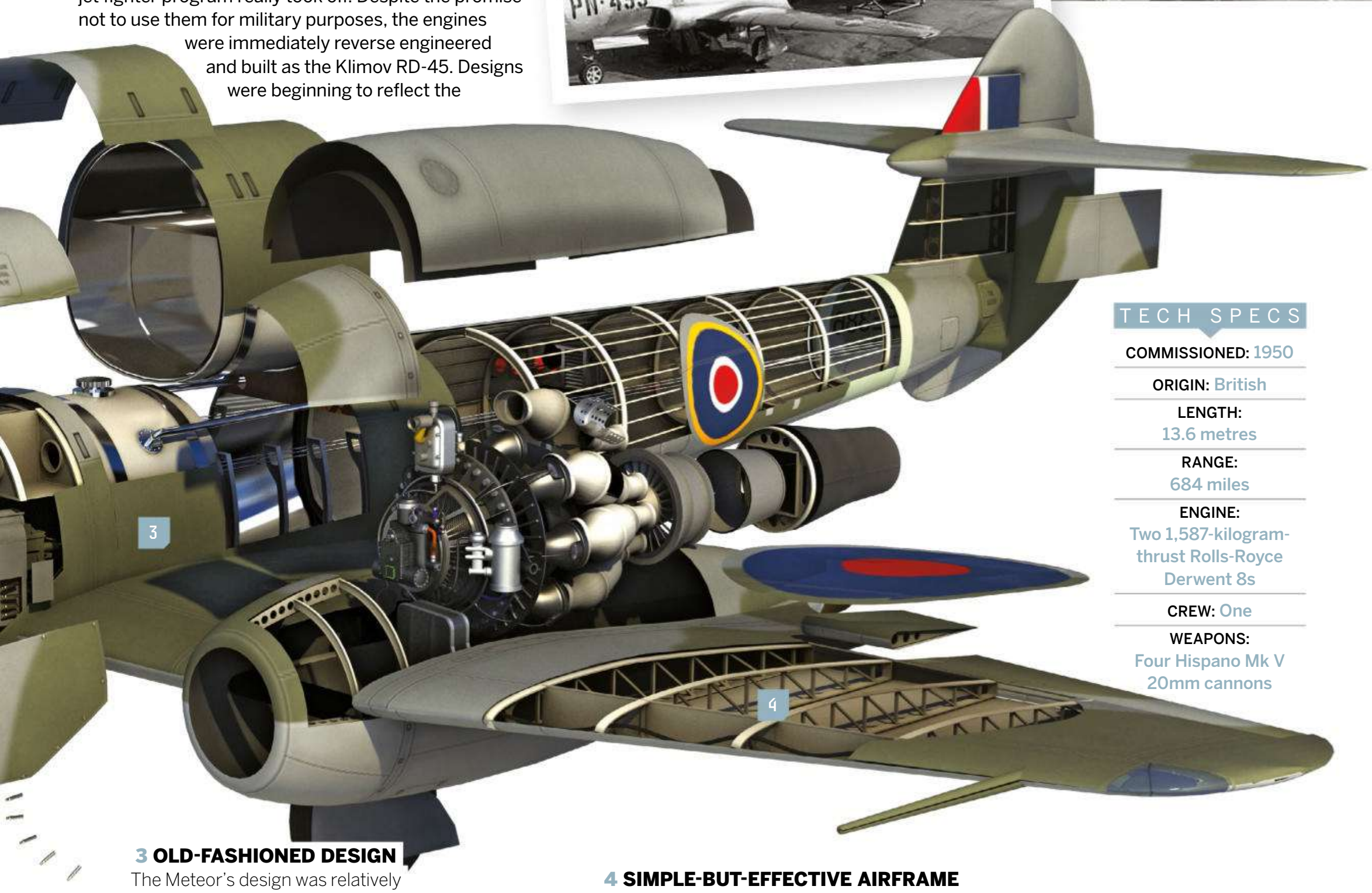
following the war, the Meteor would go through numerous upgrades and new marks, rapidly increasing in speed and performance, setting several speed and altitude records and serving in air forces around the world into the 1960s. The Me 262 briefly remained in production by a Czechoslovakian company, but only 12 more would be built. It was too crude and unreliable for post-war markets.

Britain dominated global jet fighter production at the end of World War II. Many post-war designs – the 'first generation' of jet fighters – were already well advanced in their development by the summer of 1945. The twin-boom-tailed de Havilland Vampire had entered production in 1944, and many other land and naval fighters followed in 1945 and 1946. The first US jet fighter, the Lockheed P-80 Shooting Star, was already arriving in France in early 1945, but relied on essentially British engines.

The Soviets, meanwhile, were also developing their plans. Work began in 1944 on the Sukhoi Su-9, which first flew in 1946. It was essentially a copy of the Me 262 using copies of the Jumo 004 engine. Like the originals, these proved problematic, and it was only when the British sold the Soviets a number of Rolls-Royce Nene engines in 1946 that the Soviet jet fighter program really took off. Despite the promise not to use them for military purposes, the engines were immediately reverse engineered and built as the Klimov RD-45. Designs were beginning to reflect the

America's first jet fighter, the Lockheed P-80 Shooting Star, had the engine in the fuselage but was otherwise quite conventional

The Lockheed P-80 Shooting Star production line in 1945



TECH SPECS

COMMISSIONED: 1950

ORIGIN: British

LENGTH: 13.6 metres

RANGE: 684 miles

ENGINE: Two 1,587-kilogram-thrust Rolls-Royce Derwent 8s

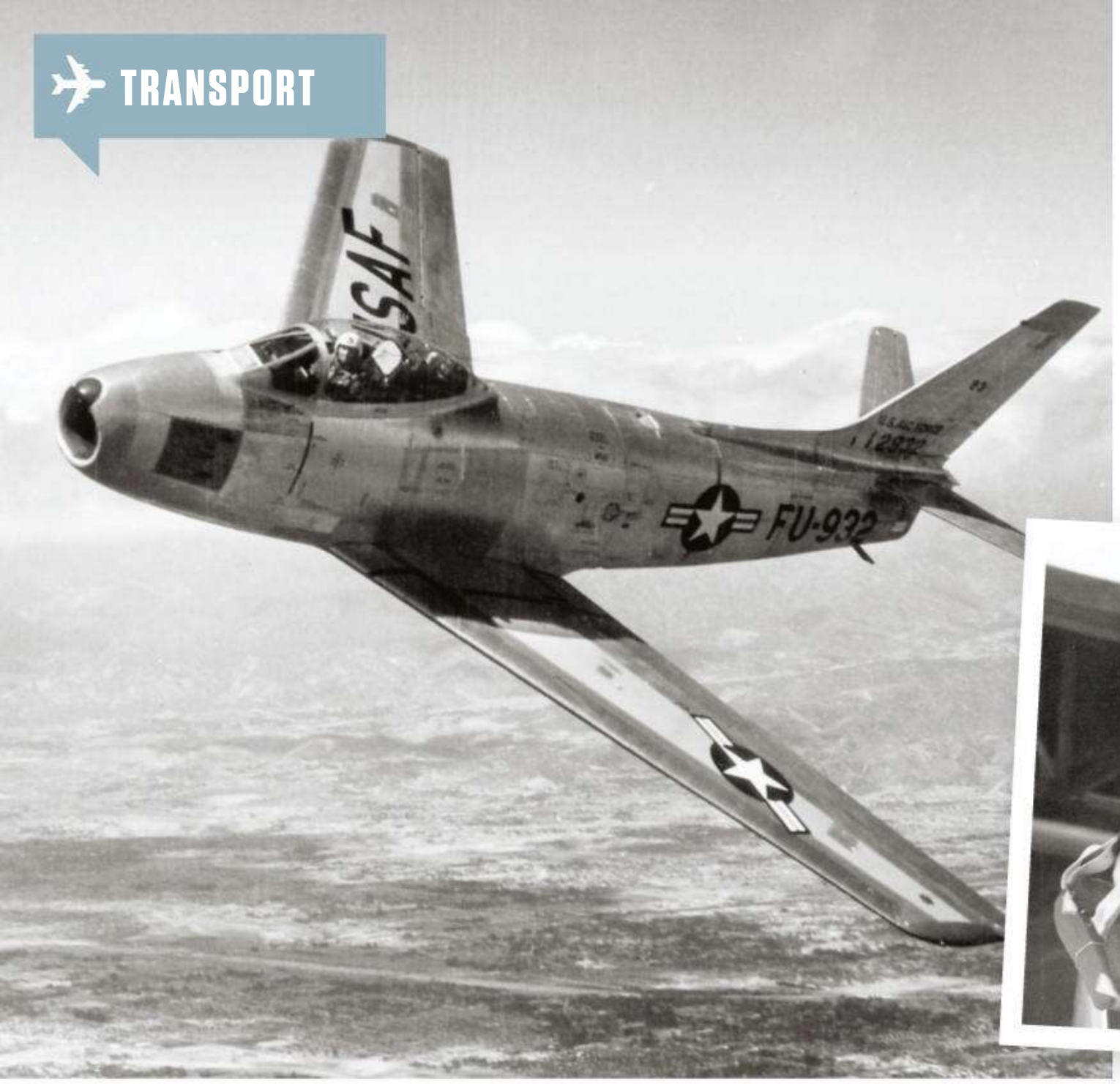
CREW: One

WEAPONS: Four Hispano Mk V 20mm cannons

3 OLD-FASHIONED DESIGN
The Meteor's design was relatively conservative, without the radical lines of some contemporary jet aircraft. But this sped up testing and production.

4 SIMPLE-BUT-EFFECTIVE AIRFRAME
The Meteor's classic monocoque airframe was old-fashioned in some ways, but it was simple, easy to produce and versatile.

© Alamy



freedoms and new aerodynamics that jet engines brought, but only in gradual increments. It would take another war to show that a leap in thinking was actually needed.

The Me 262 and the Meteor never met in combat, and it would be six years until jet fighters would fully come of age and face the ultimate test. When communist North Korea invaded South Korea in 1950, the Western Allies – under the auspices of the United Nations (UN) – sent forces to their aid. This drew communist China and the Soviet Union in to support the North, and for the first time jet fighters would meet each other in combat.

The clash between the North American F-86 Sabre and the Mikoyan-Gurevich MiG-15 has come to dominate the popular imagination of the air war over Korea. Both were a short step forward from the Meteor and the Shooting Star, both of which also flew over Korea. They were fast enough to require swept wings and other design features to optimise their performance at high speeds, but were still distinctly first generation. They were also not the only fighter jets involved in the war. The UN countries also used other first-generation jets as fighters or for ground attacks, while both sides also still used piston-engined aircraft. In proof of the Allies' initial assessment of the jets – that they were only an incremental step forward – aircraft such as the F-51 Mustang, Hawker Sea Fury and Vought F4U Corsair dominated the UN fighter forces and at times even managed to engage and shoot down MiG-15s.

However, it was the jet-versus-jet clashes that defined the air war, even if only because they provided the last valuable lessons that would secure jets as the fighter type of choice. Both sides entered the war with aircraft technology that was creeping further beyond the limits of piston engines, but utilised many of the same weapons, avionics and tactics. Dogfights between jets armed with cannons and machine guns became the norm, but it also became clear that an engine and airframe were not all that was needed to make an effective jet fighter. Higher speeds also meant smaller engagement envelopes and briefer chances to actually shoot at the enemy. The standard weapons systems struggled to keep up; the MiG-15 initially used a direct copy of the RAF's Mk IID gunsight, as used during the Battle of Britain, while its heavy cannon had a ponderously slow rate of fire. The Sabre's gunsight, with a temperamental radar-linked system, was more effective but still limited. Aircraft could be as fast and manoeuvrable as they liked, but a fighter that cannot hit another aircraft is useless.

The lessons of Korea were coupled with the incremental development that was leading to the first supersonic designs in America, Britain and the Soviet Union. Radar was needed to detect aircraft at the much greater distances needed to manoeuvre jets into position, and to assist in guiding gunfire. Better yet, the development of air-to-air guided missiles – as opposed to the air-to-air unguided rockets used in World War II – accelerated, as did the supporting avionics.

The technological leap sought by the Germans in 1944 would finally happen in the mid-1950s. By the end of the decade the speed and potential of the jet fighter led to them becoming a clear class of their own as the second generation of aircraft far surpassed piston-engined types. Designed and built as complete weapons systems, aircraft such as the English Electric Lightning, Lockheed F-104 Starfighter and the Mikoyan-Gurevich MiG-21 would fly at twice the speed of sound, engage distant targets with guided missiles and obey completely new sets of aerodynamical laws. The age of the jet fighter had arrived.

Above left: The North American F-86 Sabre was the peak of the first generation of jets. It had advanced aerodynamics but dated weaponry and avionics

Above top: American troops in Germany examining an abandoned Me 262 in April 1945

Above: Test pilot Lawrence Clousing boarding a Lockheed P-80 aircraft

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				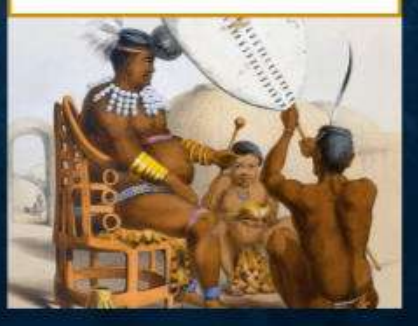

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WHY DO CARS HAVE TYRES?

How these rubber rings help vehicles get from A to B and stay safe on the roads

WORDS **SCOTT DUTFIELD**

Since the early 1800s, tyres have been helping people get around smoothly, without the bump and grind of wooden or metal wheels. To help propel a vehicle forwards, cars and their tyres engage in traction with the surface of the road through a principle of physics called rotational force, also known as torque. As if biting down on the road, traction secures a rotating tyre to the road under the weight and directional movement of the vehicle.

The area on a tyre at which traction occurs is called the contact patch. But substances like water, mud and snow can prise apart the jaws of traction, causing the tyre to spin more rapidly. To prevent this, tyre manufacturers use grooves, known as treads, to disperse or redirect these enemies of traction away from the contact patch to prevent spin.

To support the weight of a vehicle and its cargo, tyres are filled with pressurised air. When a vehicle is overloaded with weight or a tyre is underinflated, the contact patch increases and the walls of the tyre bulge. At the point at which a tyre can't support the weight of the vehicle, the walls rupture and the tyre becomes 'flat'. To help prevent ruptures, tyres have to be made from robust materials, such as thick rubber.

Did you know?

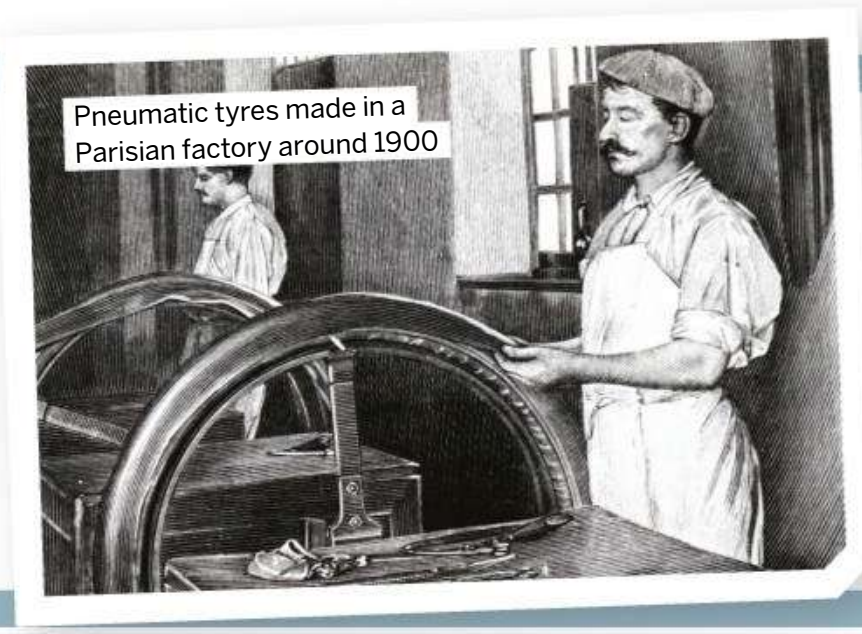
In 2022, 2.7 billion tyres were made globally

Rubber is a natural polymer sap produced by plants such as Pará rubber trees (*Hevea brasiliensis*). In a process called vulcanisation, a tree's liquid rubber sap is heated with sulphur to glue all the polymer molecules together and create sheets of durable rubber. Around 70 per cent of the world's production of natural rubber is to supply material for tyre production. However, natural rubber production can be costly to the environment through waste pollution and the loss of natural habitats as rubber tree plantations are expanded.

Rubber tapping Pará trees in Thai Mueang, Thailand

FIRST TO HIT THE ROAD

The tyre was invented by Scottish engineer Robert Thomson, who patented a design for the pneumatic tyre in 1845. Thomson's novel tyres, called 'aerial wheels', used a hollow leather tyre that enclosed a rubberised fabric tube filled with pressurised air. The tyre was then bolted to a metal rim as a complete wheel. Aerial wheels were originally designed to be placed on horse-drawn carriages and could travel for more than 1,200 miles before wearing out. Unaware of Thomson's design, another Scottish inventor named John Boyd Dunlop 're-invented' the same tyres for bicycles and then for automobiles in the 1890s.

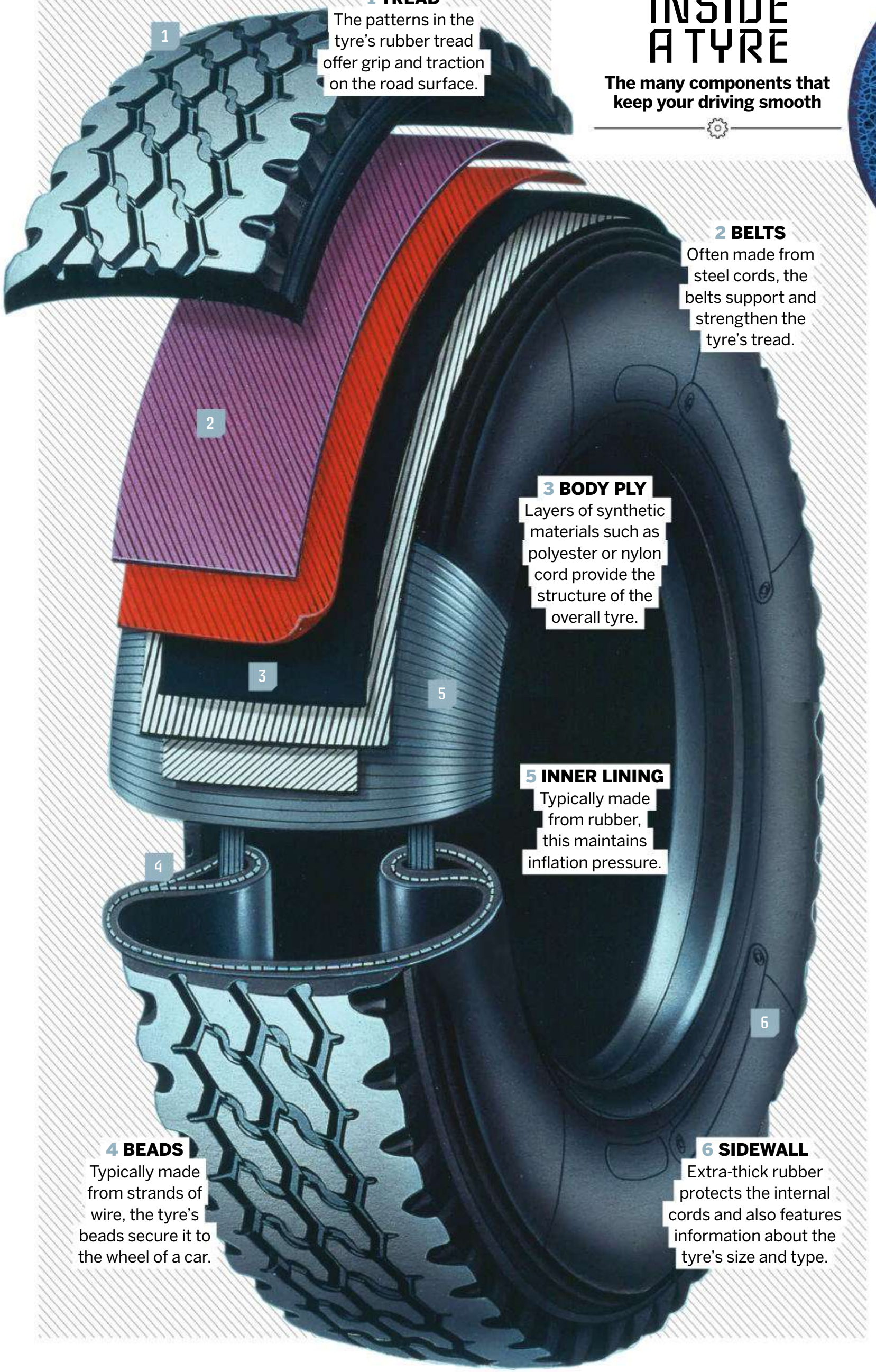


Pneumatic tyres made in a Parisian factory around 1900

DID YOU KNOW? The contact area of a tyre is around the size of the palm of your hand

INSIDE A TYRE

The many components that keep your driving smooth



1 TREAD
The patterns in the tyre's rubber tread offer grip and traction on the road surface.

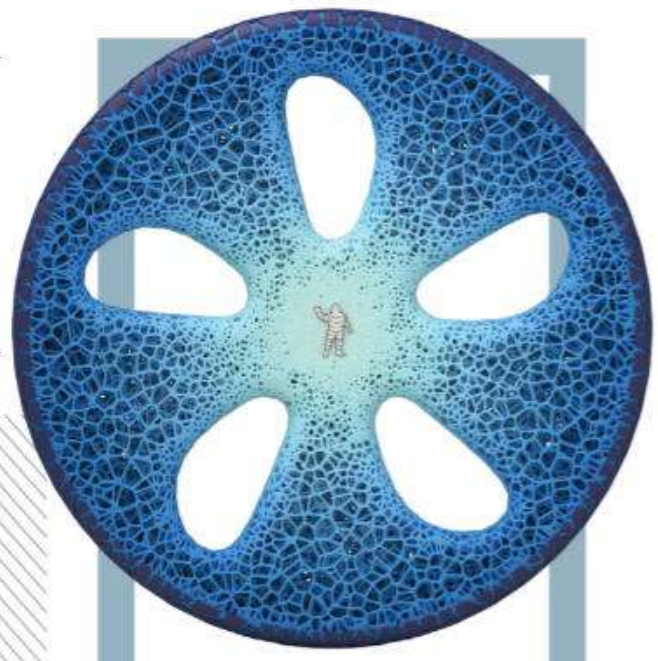
2 BELTS
Often made from steel cords, the belts support and strengthen the tyre's tread.

3 BODY PLY
Layers of synthetic materials such as polyester or nylon cord provide the structure of the overall tyre.

5 INNER LINING
Typically made from rubber, this maintains inflation pressure.

4 BEADS
Typically made from strands of wire, the tyre's beads secure it to the wheel of a car.

6 SIDEWALL
Extra-thick rubber protects the internal cords and also features information about the tyre's size and type.



The concept design for Michelin's sustainable tyres

TYRES OF THE FUTURE

Michelin, one of the world's leading tyre manufacturers, is developing a next-generation airless and sustainably sourced tyre called VISION. Unveiled as a concept in 2017, VISION may one day completely change the way tyres are made.

In its proposed designs, Michelin is investigating the use of bio-sourced materials such as butadiene – which is derived from ethanol – airless suspension and alternative production methods such as 3D printing tread to create one of the most sustainable and long-lasting tyres ever made.

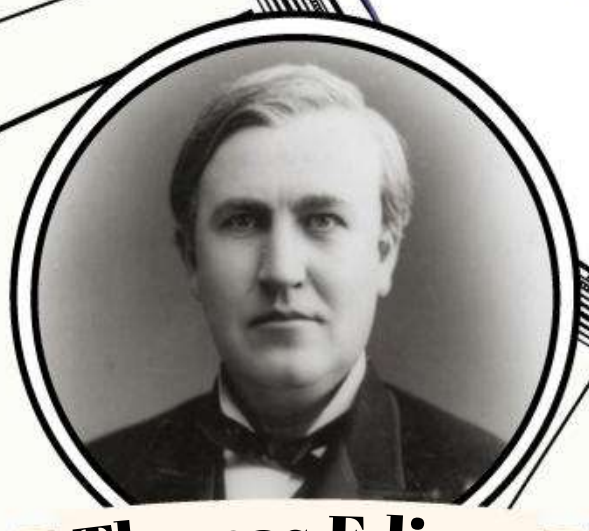
On its way to creating VISION, Michelin is set to launch its latest airless tyre, called the Unique Puncture-proof Tire System (UPTIS), to market in 2024. UPTIS is made from glass fibre-reinforced plastic that uses V-shaped 'spokes' to support the weight of the vehicle and replaces air-filled tyres. Michelin hopes to have a completely realised VISION tyre available by 2050.

© Getty / Michelin

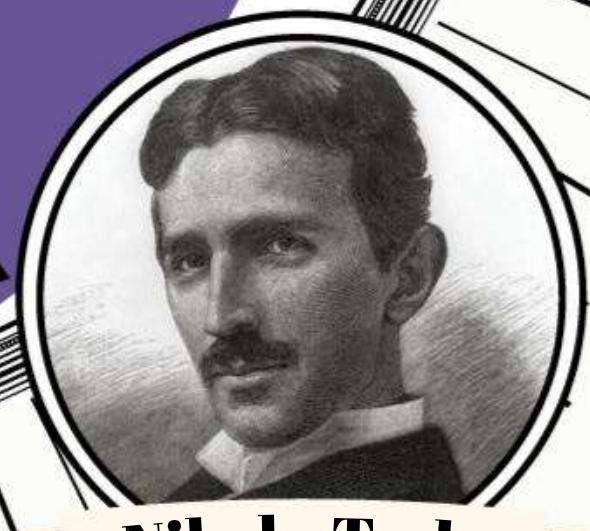
HOW THE WORLD TURNED ELECTRIC

WORDS **GAVIN THOMAS**

From battery to bulb, find out how electricity was harnessed and used to light up the planet, sparking the most productive period of technological innovation ever seen

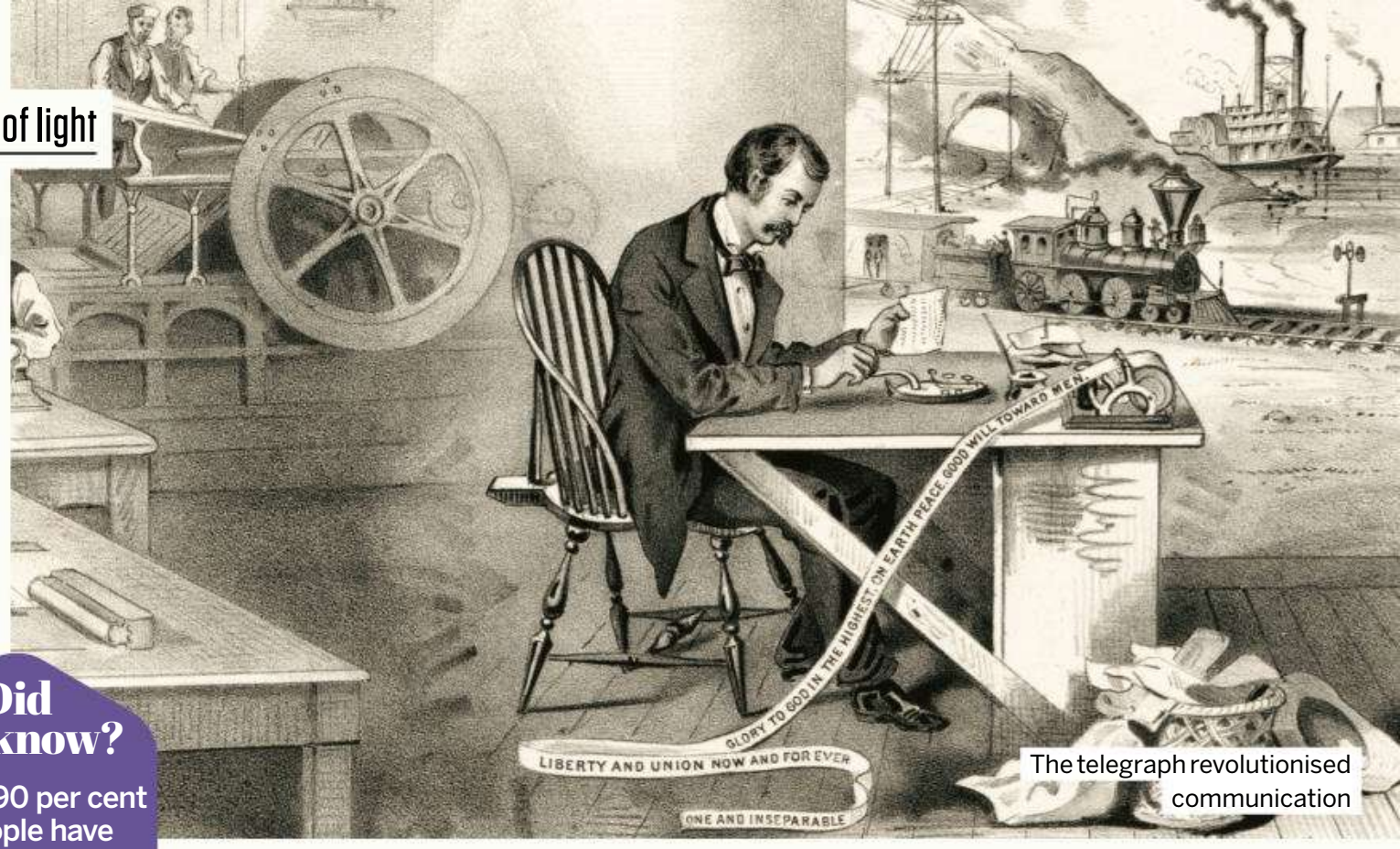


Thomas Edison



Nikola Tesla

DID YOU KNOW? Electricity travels at the speed of light



The telegraph revolutionised communication

Menlo Park was aglow. After months of work at his New Jersey laboratory – not to mention hours of painstaking work to make the first filament, which had snapped – Thomas Edison's light bulb had finally switched on in October 1879. With the second filament fitted and all the air pumped out of the bulb using the latest suction equipment, the bulb was sealed. Inside, a small cotton sewing thread that had been lightly burned to coat it with carbon hung between the terminals of the electric circuit, and right then it was glowing with heat and light.

The bulb burned all day, and once Edison connected the improved second bulb, it burned for 40 hours. Staring at it, satisfied, he said: "I think I've got it. If it can burn 40 hours, I can make it last a hundred." He wasn't wrong. This pivotal moment represented the point in the history of electricity that the spark – the idea of electricity – hit the filament and illuminated the real potential of electric energy for the whole world.

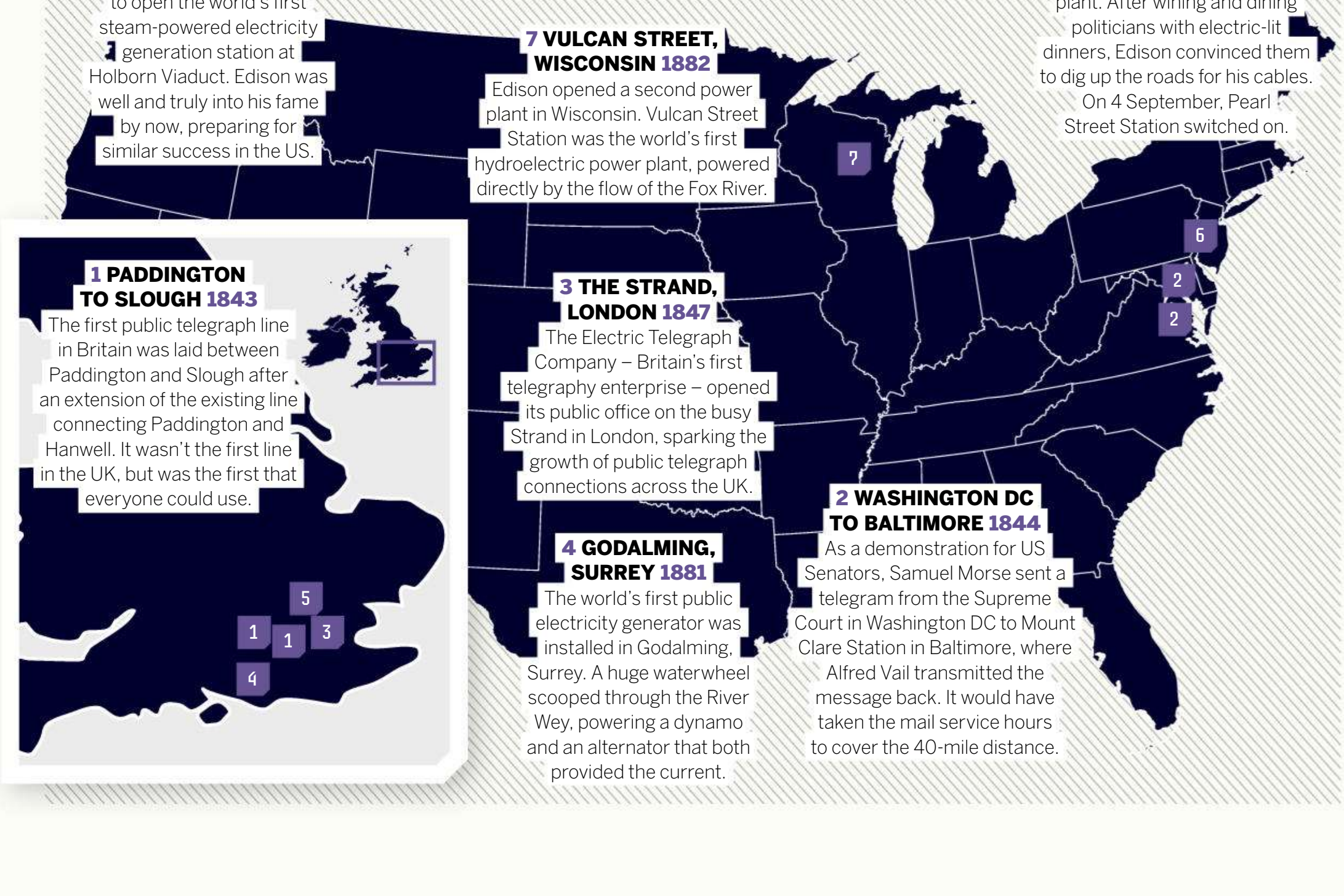
Did you know?

Around 90 per cent of people have access to electricity

While the light bulb had already been invented, what Edison did was commercially produce it so that it was cost-effective enough for everyone to afford; he wanted to light up the world. And while he did, the story begins just over a hundred years earlier with an Italian scientist named Luigi Galvani, who noticed something peculiar about the frogs' legs he had been using for experiments in his laboratory. Galvani had observed that, whether it was thundering outside or a fine afternoon, the frogs' legs would occasionally twitch. A physician, physicist and philosopher, he was investigating all kinds of things with gusto, and on this occasion it was bioelectricity. He hung the legs

THE GLOBAL SWITCH-ON

The UK and US received the first infrastructure



1 PADDINGTON TO SLOUGH 1843
The first public telegraph line in Britain was laid between Paddington and Slough after an extension of the existing line connecting Paddington and Hanwell. It wasn't the first line in the UK, but was the first that everyone could use.

2 WASHINGTON DC TO BALTIMORE 1844
As a demonstration for US Senators, Samuel Morse sent a telegram from the Supreme Court in Washington DC to Mount Clare Station in Baltimore, where Alfred Vail transmitted the message back. It would have taken the mail service hours to cover the 40-mile distance.

3 THE STRAND, LONDON 1847
The Electric Telegraph Company – Britain's first telegraphy enterprise – opened its public office on the busy Strand in London, sparking the growth of public telegraph connections across the UK.

4 GODALMING, SURREY 1881
The world's first public electricity generator was installed in Godalming, Surrey. A huge waterwheel scooped through the River Wey, powering a dynamo and an alternator that both provided the current.

5 HOLBORN VIADUCT, LONDON 1882
Early in 1882, Thomas Edison came to London to open the world's first steam-powered electricity generation station at Holborn Viaduct. Edison was well and truly into his fame by now, preparing for similar success in the US.

6 PEARL STREET, NEW YORK 1882
Edison went to New York to open the first American power plant. After wining and dining politicians with electric-lit dinners, Edison convinced them to dig up the roads for his cables. On 4 September, Pearl Street Station switched on.

7 VULCAN STREET, WISCONSIN 1882
Edison opened a second power plant in Wisconsin. Vulcan Street Station was the world's first hydroelectric power plant, powered directly by the flow of the Fox River.

KEY EXPERIMENT: FACT OR FICTION?

Thought by many to be a myth – though it may have been inspired by earlier European experiments – Benjamin Franklin's key experiment led to a greater understanding of lightning conduction, though the real facts are somewhat shrouded. While Franklin didn't document the experiment himself, he did tell Joseph Priestley – an English polymath known for his sermons, metaphysical texts and political works – who then wrote down an account of his tale.

The story goes that Franklin was in Philadelphia one dark June afternoon in 1752, looking up at the steeple of Christ Church. He was waiting for his new lightning rod to be installed at the top, growing impatient. What he wanted was to come up with a way to 'draw the electrical fire silently out of a cloud before it came nigh to strike', and so protect people from the skies. Staring at the spire, he wondered if he could fly a kite right into the storm clouds, where it would be surrounded by thunderous opportunities.

First, Franklin tied a silk ribbon to the loop of a key – this was his handle, and it had to remain dry. Then he took another silk ribbon, tied that to the key, and also to the end of a kite string; this would get wet in the rain, and the water would conduct the electricity into the key. With his son William watching, Franklin sent the kite aloft. He found that when his knuckles moved near the wet string, he got a little shock. Lightning rods would save countless others from much bigger shocks.

Founding Father Benjamin Franklin was the first to invent the lightning rod in the mid-18th century

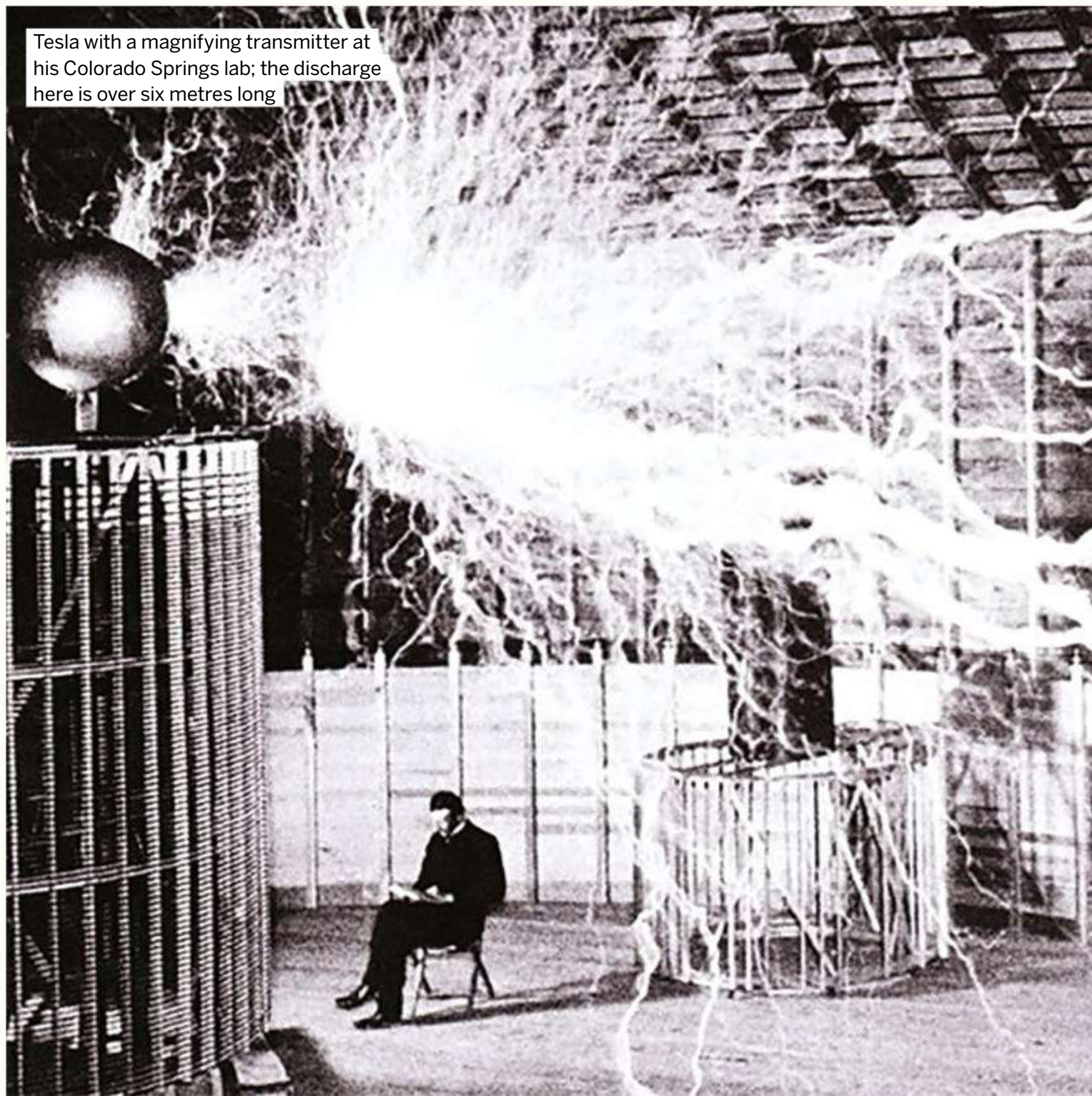
with brass and iron, so he surmised that fluid in and on the limbs was conducting electricity somehow, and he was determined to work out how it made the muscles jerk. He wrote an essay about it that was later read by a physicist from Como in northern Italy called Alessandro Volta. Volta – for whom the volt, the unit for electrical potential, was named – read this report and heartily disagreed. He set about to disprove the findings of Galvani's research and began repeating the experiment soon after the paper's publication.

He discovered that there was indeed the occasional jolt of the leg – a result of the reaction between the dead frog, his metal knife and the metal table in his workshop. Clearly, the leg was conducting electricity between the two different kinds of metal. Encouraged, he continued to experiment using different kinds of metal. It was crucial work, because the great switch-on wouldn't have been possible if it hadn't been for Volta's development of the battery.

His work progressed, and he eventually moved from pegs and nails to plates of solid zinc and silver, with salt-soaked cardboard pads that sat between them in place of frogs' legs. Each pair of plates, the cell, would provide a little electricity if a circuit was made using the two terminals: one zinc and one silver. When Volta stacked the cells up in 1800, he found that they produced far more power collectively, and so the first voltaic pile – the earliest battery – was created. By 1801 he was so famous for it that he got to show it to the emperor of France, Napoleon Bonaparte, who made him a count and a senator. It was the first time in history that someone had managed to store electricity for future use, paving the way for the development of generators.

> "It was crucial work, because the great switch-on wouldn't have been possible if it hadn't been for Volta's battery"

Just two decades later, English scientist Michael Faraday had produced the first-ever motor that was powered by a battery. He'd been inspired by the work of people like Hans Ørsted, who discovered electromagnetism, and also William Wollaston and Humphry Davy, with whom he'd been discussing the problem of electric motors before creating his series of homopolar motors. While the earlier models were too inefficient to use, in 1831 he produced the first electromagnetic generator, based upon the principle of electromagnetic induction that he'd established the year before.



Tesla with a magnifying transmitter at his Colorado Springs lab; the discharge here is over six metres long

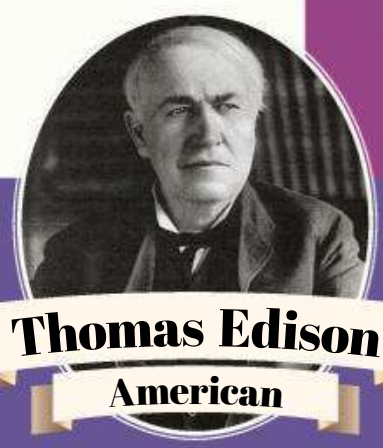
DID YOU KNOW? A bolt of lightning can measure up to 3 million volts

These generators turned mechanical energy – eventually driven by steam power – into electrical energy, and were a vital element of the great switch-on. The generators provided a steady voltage – in both senses – that could be used for all sorts of things, like sending and receiving telegraphs. Since electricity had been laid in cables, there had been an explosion of creativity among scientists, engineers, craftsmen and general tinkerers everywhere, and as such a number of people were working on this innovation at the same time. The telegraph connected two places by means of a long wire, through which a message could be encoded in the pulses of current that travelled along it, enabling information to be exchanged at an astonishing rate.

The first public telegraph lines were laid in England between Paddington and Slough – a distance of about 20 miles – in 1843, and on 24 May the following year Alfred Vail and Samuel Morse displayed the telegraph in action to a group of US Senators. Morse sent a message from the Supreme Court in Washington DC to Mount Clare

Did you know?

Electric fields can either attract or repulse

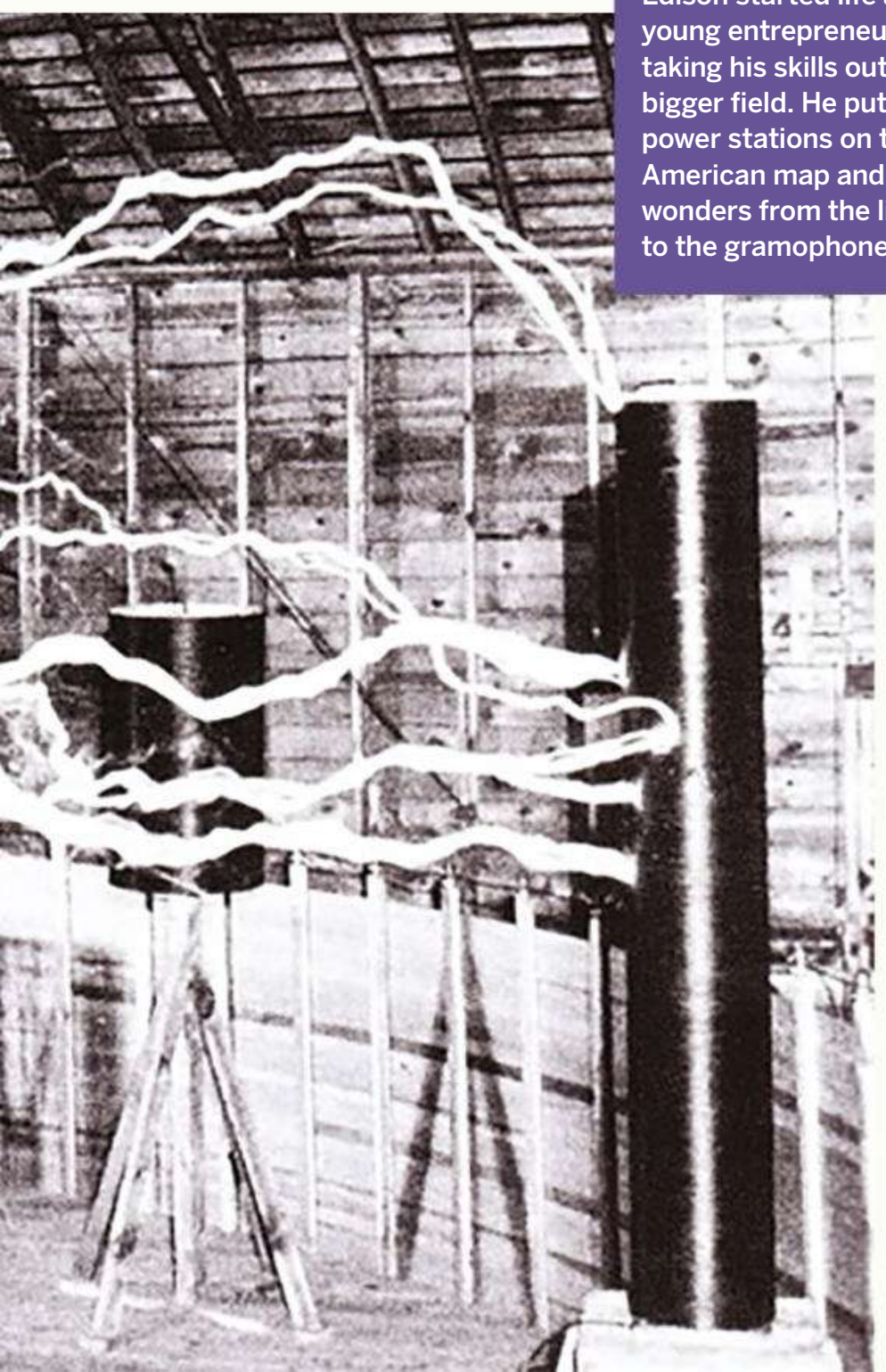


Thomas Edison

American

1847 to 1931

A ruthlessly determined and hard-working engineer, inventor and note-taker – he filled over 3,500 notebooks documenting his ideas and experiments – Edison started life as a young entrepreneur before taking his skills out to a bigger field. He put the first power stations on the American map and created wonders from the light bulb to the gramophone.



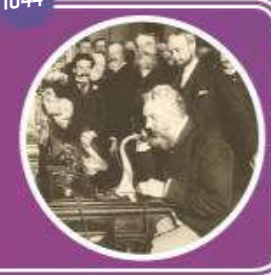
LIGHT BULB MOMENTS

1800 — Volta: the first pile (battery)

1817 — Faraday: first dynamo

1831 — Faraday: first electromagnetic generator

1844 — Morse and Vail: sent the first telegram



1876 — Bell: first telephone call

1877 — Bell: first commercial telephones

1879 — Edison: first commercially viable light bulb

1877 — Edison: first phonograph (gramophone)

1881 — A printing works: first electric-lit factory

1882 — The Electrical Exhibition at Crystal Palace, London

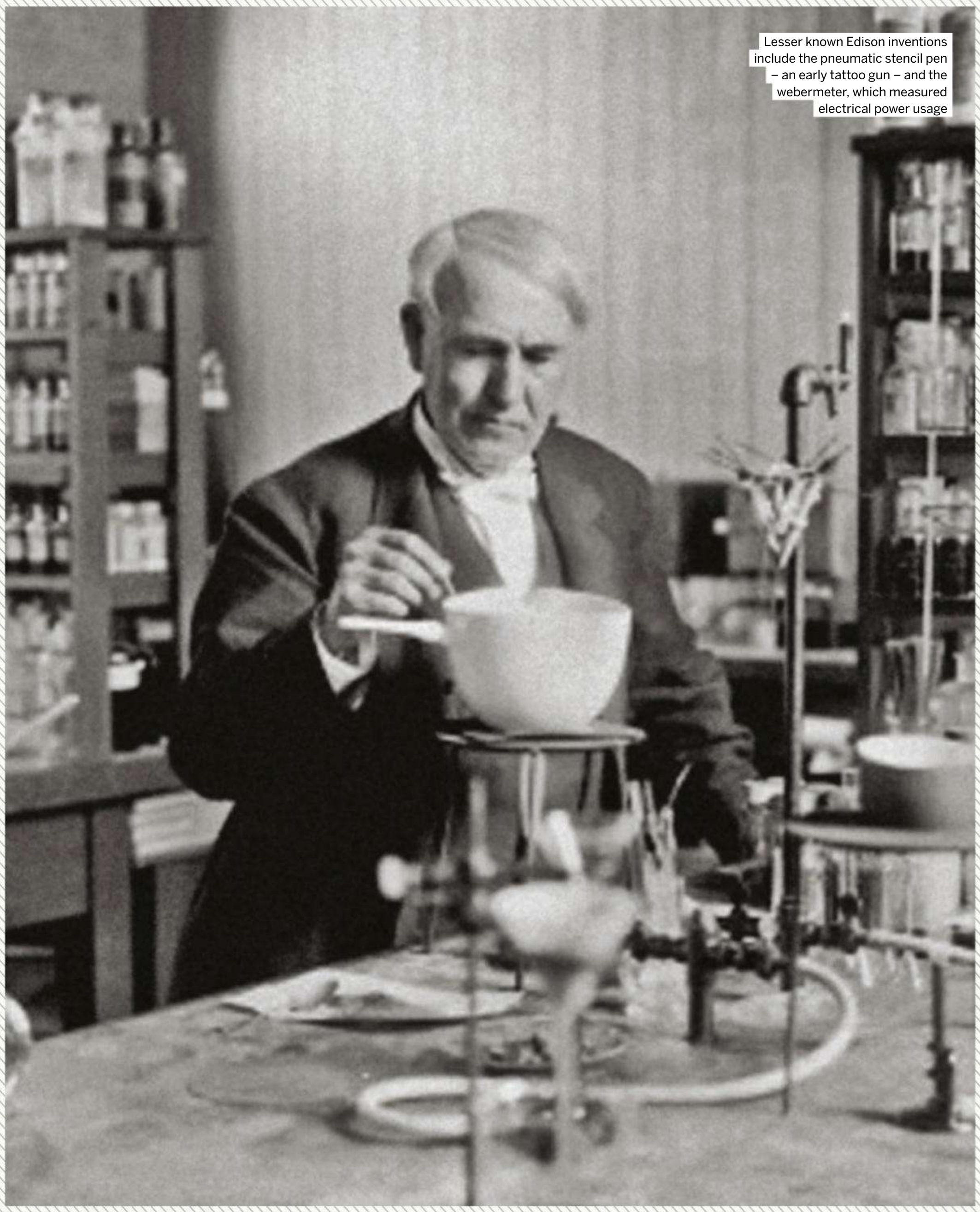
1882 — Vulcan Street, Wisconsin: first hydroelectric power plant

1882 — Pearl Street, New York: first power station

1890 — Edison General Electric formed, later just GE

1896 — Marconi: first radio transmitter patented

1925 — Baird: first TV transmission



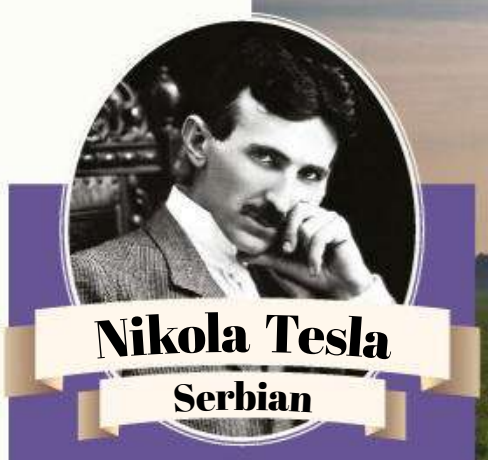
Lesser known Edison inventions include the pneumatic stencil pen – an early tattoo gun – and the webermeter, which measured electrical power usage

Station in Baltimore, where his colleague then transmitted back to Morse. It travelled faster than an express train, and certainly faster than the mail. Back in London, 1847 saw the Electric Telegraph Company open its Strand office to the public, offering pay-per-ticket access to the machines. In Ohio, it saw the birth of the most influential figure in the great switch-on: Thomas Alva Edison.

Born an entrepreneur, Edison had always had an eye for business, and growing up in Port Huron, Michigan, he never missed an opportunity. He was selling newspapers in town one day in 1862, while the Battle of Shiloh raged in Tennessee, and wondered if he could somehow get the word out. Telegraphs were indispensable during the Civil War and had been used to carry field reports back and forth since the year before. Edison convinced his friend in Detroit – a fellow telegrapher – to wire newsflashes over to him, and as they came in Edison then chalked up live battle updates onto his headline boards. He was 15 years old and sold hundreds of newspapers that day, at twice the usual price. A tireless inventor in later life, young Edison was quite the telegrapher in those days, once beating the fastest sender in New York in a telegraphing race. He taunted the frustrated New Yorker with the quip: "Say, young man, change off, and send with the other foot!"

Instant communication changed the world, and electric generators made it possible. Telegraphs, however, were only the beginning. Telephones were about to make it possible to speak with your own voice, rather than learn Vail and Morse's complex code and tap out messages, and this was down to a Scottish-born inventor called Alexander Graham Bell, who later became a naturalised US citizen. He founded a school for the deaf in 1872 and spent much of his life working on the electric hearing aid, motivated to help his wife, Mabel Hubbard, who was deaf. While he may not have been the first person to invent it, it did lead to the development of his telephone.

The first telephone call was to Bell's assistant, Thomas Watson, on 10 March 1876. "Mr Watson, come here. I want to see you," were the first words uttered on the phone, picked up by the receiving microphone. The device spread like wildfire. Bell and the Bell Company would be forced to defend its patent in around 600 legal cases. Meanwhile, Edison had moved to a lab in Menlo Park, New Jersey, where he began improving the telephone.



Nikola Tesla

Serbian

1856 to 1943

A physicist and electrical engineer famous for his development of the induction motor, a wide range of electrical devices and a power system that bettered Edison's own, Tesla was a proponent of alternating current – the type we all use today when we access mains electricity from the wall.

Modern infrastructure allows electricity to travel great distances

A year later, in 1877, he was experimenting with a diaphragm one day, watching it vibrate, when it occurred to him that the vibrations from the diaphragm would make a stylus joggle up and down. He tested the idea out and managed to make some dents in a piece of paper by reciting the nursery rhyme *Mary Had a Little Lamb*; when he pushed the stylus back through the dents, he could hear the sound that he had recorded in the paper. This revelation led to the creation of the phonograph, later called the gramophone, and the first known recordings of nurse Florence Nightingale, explorer Henry Stanley and poet laureate Alfred Tennyson.

This work on sound recording contributed to Edison and his team's work on a new carbon microphone that was louder, clearer and worked across a much greater range. Western Union bought his improved telephone, or 'speaking telegraph', for $100,000, and Edison asked to be paid the sum in annual instalments for 17 years. He had set himself up for life and could now dedicate himself wholly to his original task: to bring electricity to the world.

Did you know?

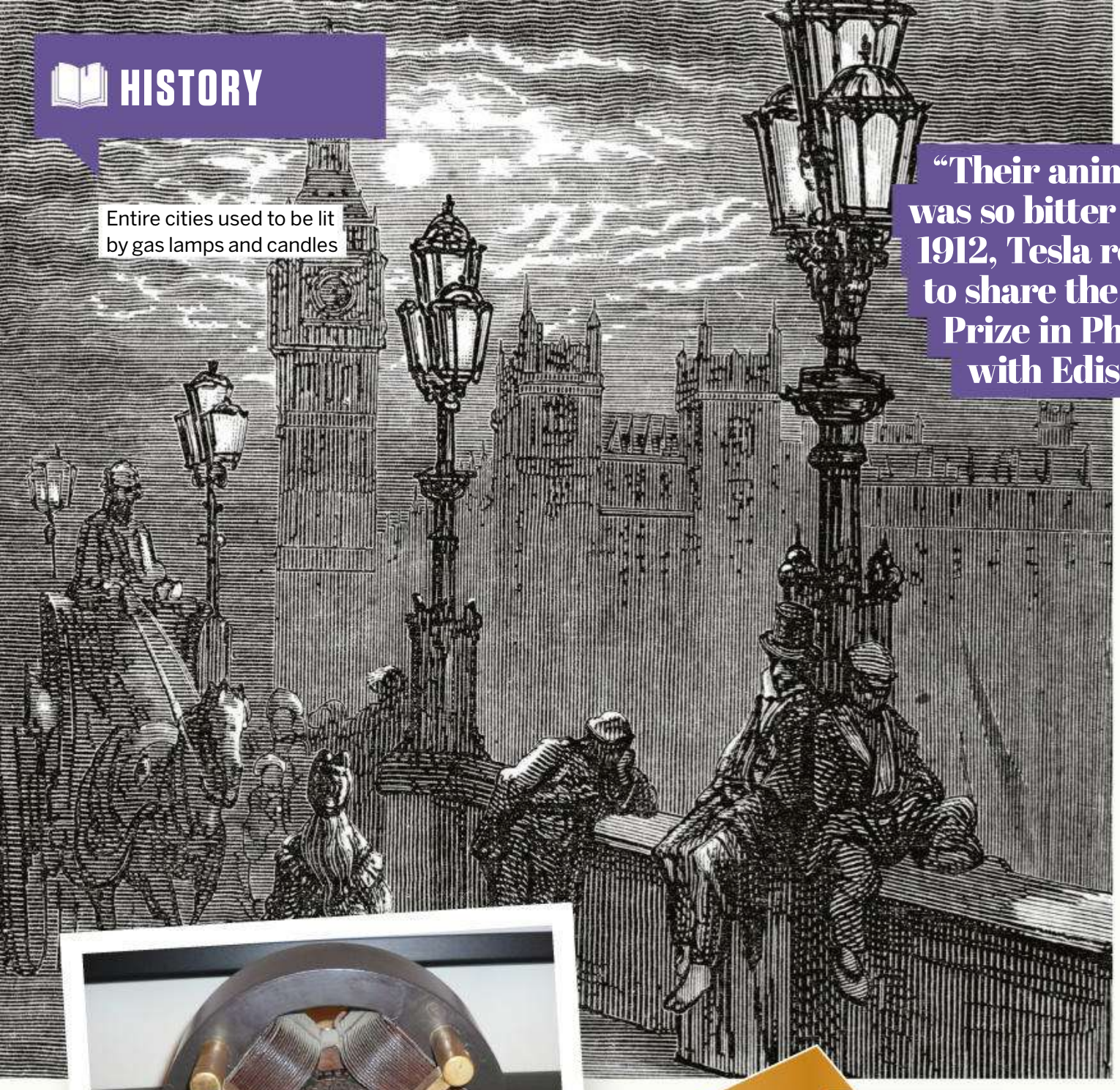
Electricity causes muscle cells in the heart to contract

Many people had been trying to develop the electric light. Since the 1840s they'd been passing currents through platinum or carbon filaments inside vacuum-filled bulbs of glass. The problem was that they burned out too quickly. Joseph Swan had led the charge in Britain with his battery-powered bulb in 1860, but his vacuum was too poor to sustain the right conditions. He continued working late into the 1880s, but it was Edison who realised the light bulb commercially following his success with the first two bulbs, using the latest air pump to achieve a better vacuum.

Since then, Menlo Park had been gathering crowds who travelled for miles to enjoy the spectacle – though Edison and Swan did team up later to fend off competitors, with Edison beginning to release bulbs of varying sizes and shapes to saturate the market. In 1881 the first electric light bulb factories opened in Newark, New Jersey, in the US and Benwell, Newcastle upon Tyne, in the UK. Heavy generators like the steam engine 'Long-Waisted Mary Ann' were used to power bigger machines. But Edison wasn't about to rest on his laurels.

He started planning a new kind of infrastructure. Edison was going to divide a

"Since electricity had been laid in cables, there had been an explosion of creativity among scientists, engineers, craftsmen and general tinkerers everywhere"



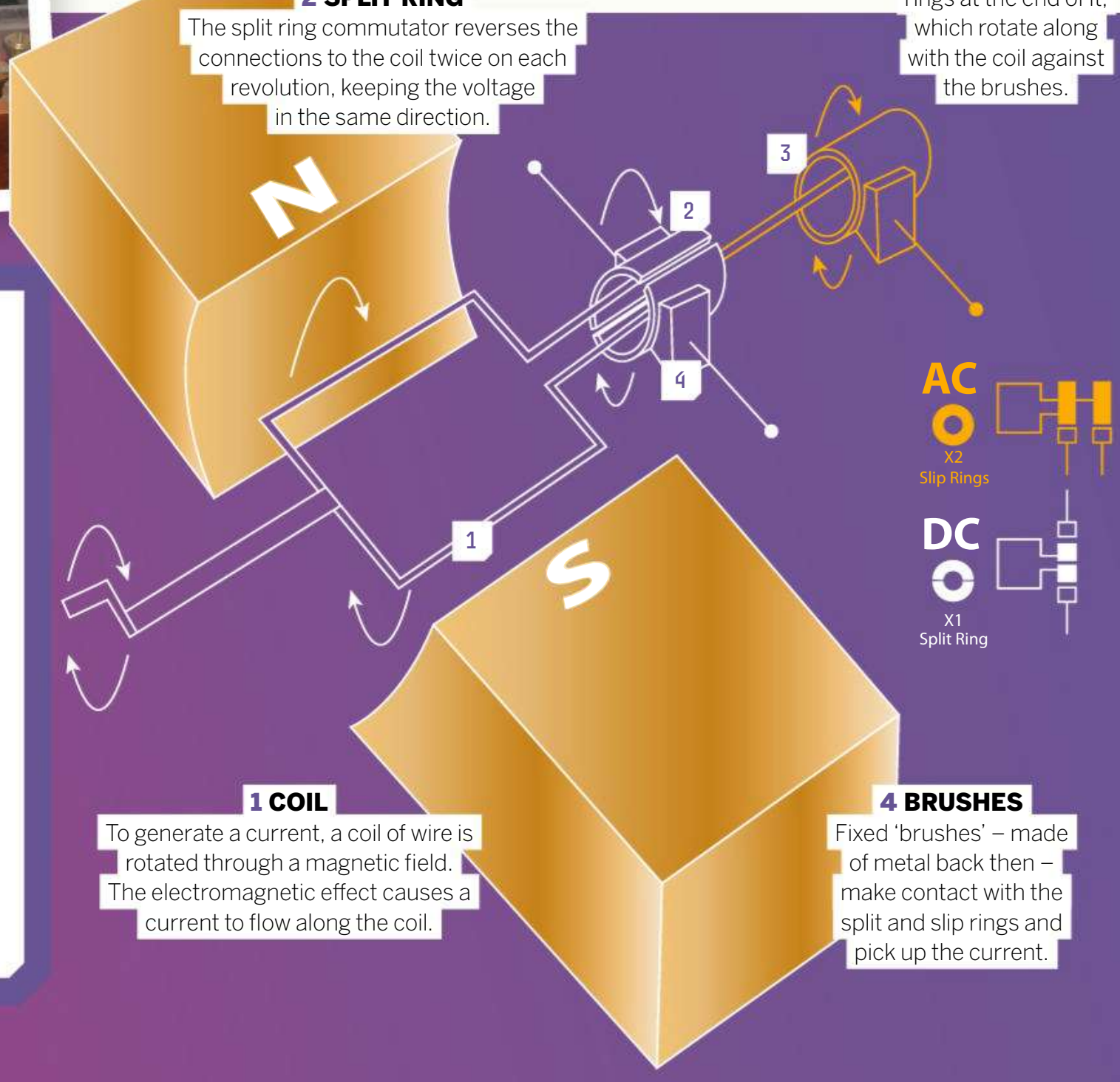
Entire cities used to be lit by gas lamps and candles

"Their animosity was so bitter that in 1912, Tesla refused to share the Nobel Prize in Physics with Edison"

city into sections, each connected to the main generator, in order to provide power to anywhere needed, so long as you could connect to a grid of cables. This meant that he and his team had to design new generators, cables, fuses, switches, meters, junction boxes and insulators, because none of them existed yet. Most still read by candlelight, with the exception of J. P. Morgan in New York, who had electric power for his lights from a steam boiler in his basement.

Pearl Street in New York was the first power station to fire up on 4 September 1882. Five companies had scrambled to light the city, but Edison had won the politicians over with a deftly electric-lit dinner at Menlo Park, where they agreed to dig up their streets for his cables. The lights came on at 15:00, and one New York journalist later commented: "It seemed almost like writing by daylight." At one point a fuse blew, but Edison took off his smart clothes and hat to get down there and mend it himself. By 30 September the Vulcan Street plant in Wisconsin had revved up too – this was the first hydroelectric plant.

The Pearl Street station was supplying 231 customers by January 1883 – and almost double that by August



2 SPLIT RING
The split ring commutator reverses the connections to the coil twice on each revolution, keeping the voltage in the same direction.

3 SLIP RINGS
The current from the coil travels to the slip rings at the end of it, which rotate along with the coil against the brushes.

1 COIL
To generate a current, a coil of wire is rotated through a magnetic field. The electromagnetic effect causes a current to flow along the coil.

4 BRUSHES
Fixed 'brushes' – made of metal back then – make contact with the split and slip rings and pick up the current.

AC VERSUS DC

AC and DC are actually more closely related than you might think when you look under the hood. A coil rotating through a magnetic field causes a voltage which changes direction as the coil moves closer to and farther from the main magnet. The difference comes from how the current is picked up from this coil. AC generators use two slip rings, while DC dynamos – a generator that uses a commutator – must utilise one split ring. While Edison's dynamos were popular to begin with, by 1888 Tesla had invented a new-and-improved AC generator. Edison claimed that AC was unsafe and tried to get any currents over 800 volts banned by law. He didn't have much luck, though, and AC quickly became the standard.

– and light bulbs now lasted for 400 hours. The technology was continually improving, and Edison walked down the streets each night, proudly watching more and more of his light bulbs switch on.

It wasn't all plain sailing, though. Nikola Tesla, the Serbian scientist who had arrived in America in 1884, filed a patent for his improved electric motor in 1888 – two years before Edison set up the Edison General Electric Company. Edison championed direct current (DC), which flowed in one direction and provided a safe voltage of 250 volts. However, its relatively low voltage meant that it was too weak to be sent across long distances.

Alternating current (AC), on the other hand, flows in pulses – first one way, building up in strength, then reversing direction – many times each second, which meant it could travel at a high enough voltage to allow for a low enough current and not destroy power lines. Despite Edison claiming it was unsafe and trying to get currents over 800 volts banned, Tesla's new invention was bought by Edison's rival George Westinghouse.

DC generators were quickly replaced by the superior AC generators, and relations were sour between Tesla and Edison. Tesla claimed that Edison had cheated him out of a $50,000 bonus for improving the dynamo while he was working for him, but Edison said he'd been joking. Their animosity was so bitter that in 1912, Tesla refused to share the Nobel Prize in Physics with Edison, and so neither of them ended up winning it.

Still, the impact that these inventors had on the world has been indelible. From the battery to the light bulb, the spark of electricity had travelled down history to these two men, and their generators put power in the households of first major cities like London and New York, then the planet. Guglielmo Marconi had developed the radio transmitter by 1896 – though had Edison gone a few steps further in his research he would have predated this invention by 20 years – and John Logie Baird transmitted the first television pictures by 1925. These were recorded using a 'scanning' disc, invented by Paul Nipkow, that controlled the amount of light from particular areas of the subject being filmed as it hit photoelectric cells.

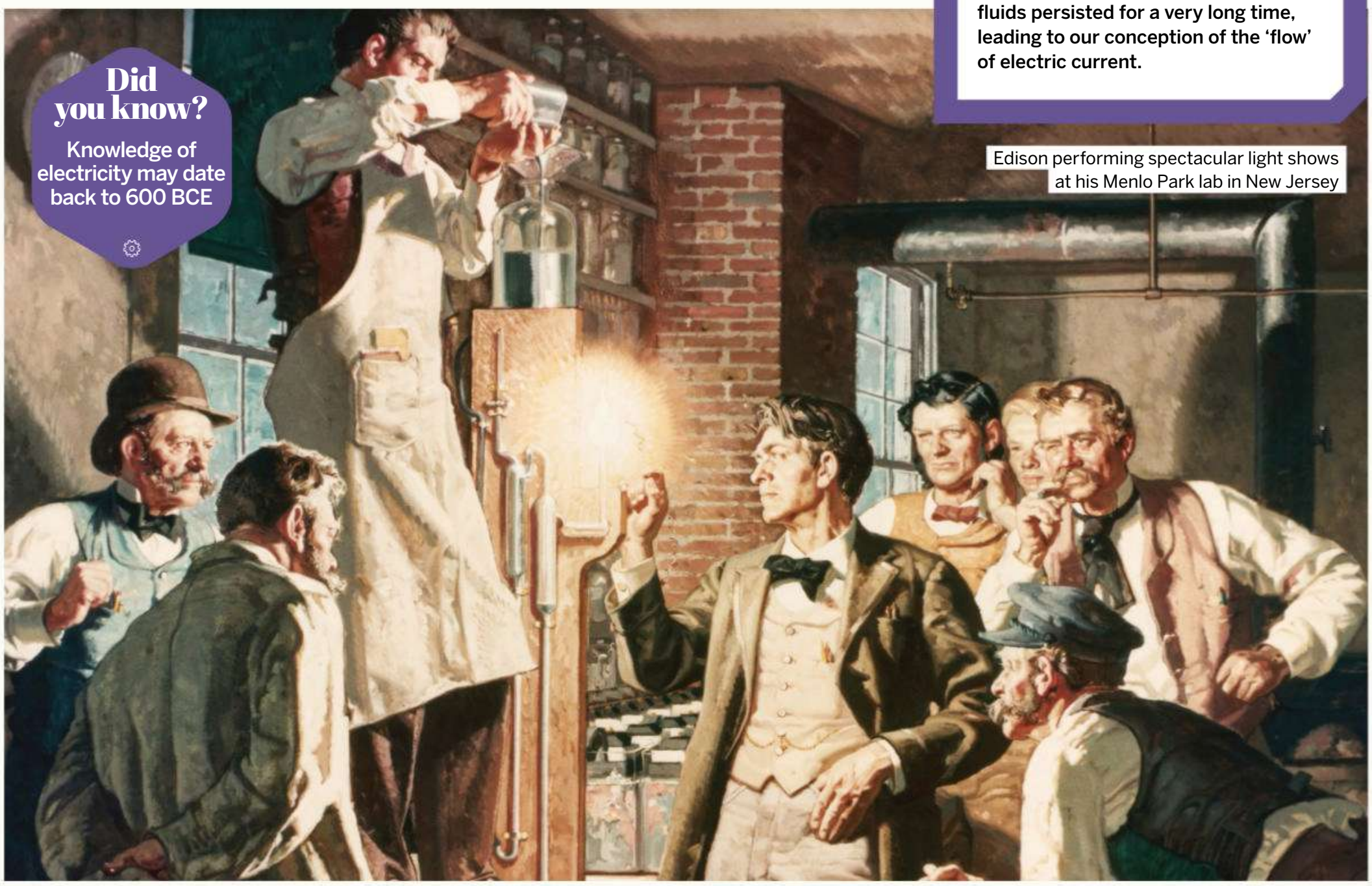
Electricity was everywhere, and it changed everything. When Edison died in 1931, the electric lights of America were switched off or dimmed in his honour. For a minute the country was as dark as it had been during the Civil War, when young Edison was listening to the telegraph humming with news and dreaming up ways to make his fortune.

THE EARLY NOTIONS

Electricity is a very slippery subject, even today. Due to the sheer number of different ways that we use the word, it can be confusing, and early investigators of electromagnetism had another problem to deal with – namely a fuzzy belief in a kind of liquid that permeated the universe called the aether.

The aether dates back to 1638, when the natural philosopher René Descartes was trying to deduce how light worked. He had already come up with three different types of matter from which he believed the universe was made, and now he was theorising that light was actually a pressure wave that travelled through one of these types of matter.

In order to make his model work, he had to work backwards to identify the properties of this type of matter that would lead to the correct calculations of the reflection and refraction of light. As it turned out, it worked kind of like a liquid, and so the notion of the aether was born. Thinking in terms of fluids persisted for a very long time, leading to our conception of the 'flow' of electric current.



Did you know?

Knowledge of electricity may date back to 600 BCE

Edison performing spectacular light shows at his Menlo Park lab in New Jersey

© Corbis; Look and Learn; Alamy

HUMAN POPULATION

Why it took just 200 years for the world's population to increase eightfold to 8 billion

WORDS **AILSA HARVEY**

On 15 November 2022, the human population reached 8 billion. The United Nations' population projection is able to calculate this using a model that incorporates fertility rates, mortality rates, migration behaviour and other factors. In each country or geographic region, different living situations influence the death and birth rates of an area. For example, access to effective healthcare increases a population's average life expectancy. Meanwhile, countries that provide good education to their female population usually have a lower fertility rate.

The planet hasn't always been dominated by humans. At the time *Homo sapiens* first evolved, there were only 100 to 100,000 of us. We were exposed to very different dangers, like large predators and exposure to the elements. Our ancestors required better survival skills to aid their hunter-gatherer lifestyles. In fewer numbers and with lower life expectancies, growth in population wasn't as rapid as today. In fact, it took 35,000 years for this early human population to double in size.

In 2022, our extensive population can be seen as a triumph of modern medicine and technological advancement, with many thousands of years of lifestyle changes. However, the environmental impact of this great number should also be considered. An increase in population is directly related to the demand for food and shelter. And for both food to be produced and homes to be made available, land is needed.

Deforestation is constantly taking place to remove native plant life – and the animals that live in these wild habitats – replacing it with farmland to grow crops to feed to people or livestock. At the same time, natural landscapes are being replaced by urban settlements. We can limit our use of Earth's resources by replacing fossil fuels with renewable energy, cut down on meat and dairy intake to decrease greenhouse gas emissions, reduce food waste and use biodegradable products. To feed 8 billion people using less land space, some scientists suggest vertical farming. By growing food in layers, surface area is added vertically, rather than taking over even more of the remaining wild landscapes.

Did you know?

There are around 140 million births a year

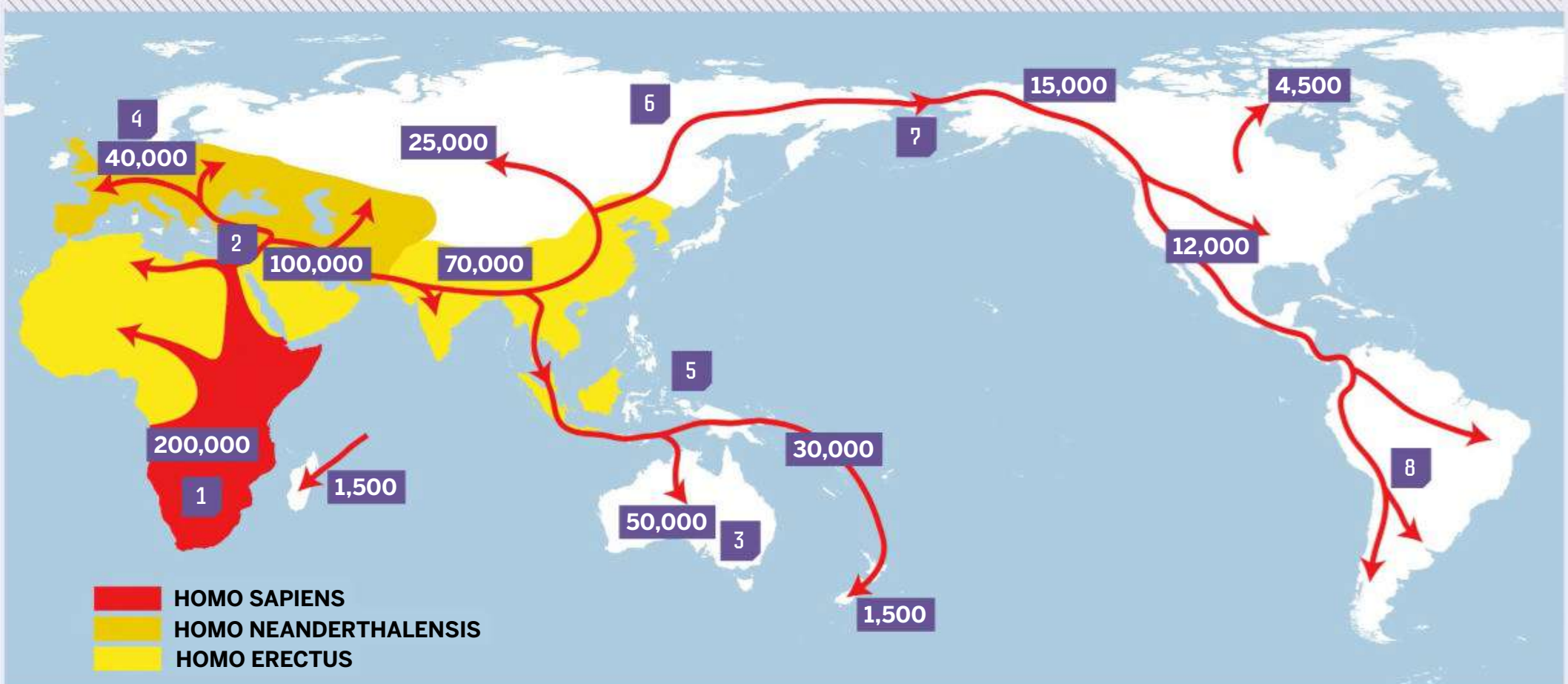
Our population is experiencing a surge in numbers due to technology tackling the main life-limiting factors, such as disease and access to food and safe water. Exactly how much more our species will expand and when Earth's human population will begin to level off is yet to be determined.

Our early hunter-gatherer ancestors numbered just a fraction of the human race today

DID YOU KNOW? Countries with the highest populations are India, China, the US, Indonesia, Pakistan, Nigeria and Brazil

THE ORIGIN OF HUMANS

Modern humans originated 200,000 years ago and began to spread across continents



1 HUMAN EVOLUTION
Around 200,000 years ago, modern humans evolved in Sub-Saharan Africa.

2 GREAT MIGRATION
Humans began to migrate across the globe 100,000 years ago. The population remained under 1 million.

3 REACHING AUSTRALIA
Around 1,000 humans sailed to Australia 50,000 years ago. After an ice age, which drastically reduced the population, numbers increased to around 1.2 million by the time European settlers arrived in 1788. Violence against Aboriginals and new diseases introduced by colonists reduced the Indigenous Australian population by up to 90 per cent.

4 NEANDERTHAL RIVALS
Homo sapiens entered Europe around 40,000 years ago. There, modern humans had to compete with Neanderthals, who had occupied the continent for at least 100,000 years.

5 CLIMATE IMPACT
By 35,000 years ago, the increase in human population slowed with the arrival of an ice age. Humans migrated farther south to avoid emerging glaciers, seeking more temperate climates.

6 END OF THE ICE AGE
15,000 years ago, the ice age ended, and glaciers stopped their advances over northern continents. The human population began to increase and migrate again.

7 BRIDGE TO THE REST OF THE WORLD
Today's global population is around 2,000 times what it was 12,000 years ago. Due to increased volumes of water becoming trapped in glaciers, sea levels decreased and a bridge of land called the Bering land bridge formed. Around 16,000 years ago, humans migrated across this, allowing them to populate the Americas.

8 POPULATING SOUTH AMERICA
Human populations reached South America around 10,000 years ago. By this time, there were around 5 million people on Earth.

FARMING BOOST

Agricultural practices emerged in human societies around 12,000 years ago. Before this, people mostly adopted the hunter-gatherer lifestyle. This meant following their food and using their mobility to benefit their survival. When people began to construct farms, making more permanent homes became necessary. This lifestyle change caused an increase in settlements, which grew in size to form the beginning of some of today's large cities.

Farming allowed communities to produce their own food and have more control over the numbers that were fed. As farms grew in size, farm owners accumulated more food than their immediate families needed, leading to the trade of fresh goods. As more food and jobs became available, it became possible for populations to grow. Today, farmland makes up around 38 per cent of the planet's total land surface area in order to accommodate 8 billion people.

The first farms emerged in the 'Fertile Crescent', a long section of land that spans Iraq, Turkey, Syria, Lebanon, Israel, Palestine and Egypt

© Getty / NordNordWest

918
SQUARE MILES
If 8 billion people gathered in one place, they would cover an area a little bigger than Tenerife

31 YEARS OLD
The global median age has increased by a decade since 1970

60%
Most of the world's 8 billion live in Asia

< 15 YEARS OLD
Nigeria has the youngest population, with 50 per cent being young children

7 COUNTRIES
50 per cent of the world's population live in just a few countries

2023
This year, India is due to overtake China as the most populous nation

68,212 PER SQUARE MILE
Monaco is the world's most densely populated country

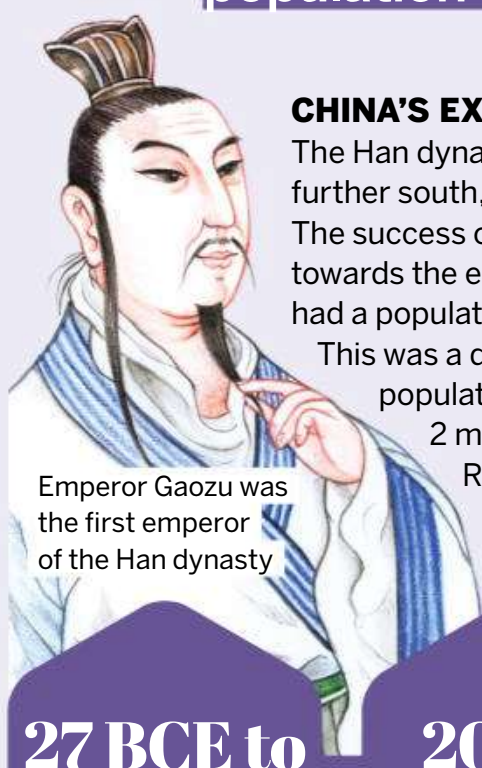
281 MILLION
In 2022, many millions live outside of their country of birth

3%
A tiny proportion of the world's population is under two years old

4 PER SECOND
Worldwide, there are 259 births per minute

THE HUMAN TAKEOVER

These events helped the human population reach 8 billion


Emperor Gaozu was the first emperor of the Han dynasty

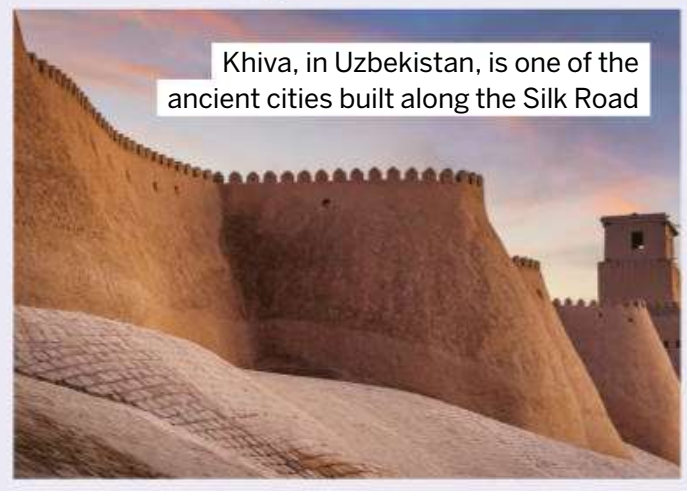
CHINA'S EXPANSION
The Han dynasty saw the Chinese go further south, down the Yangtze River. The success of this empire meant that towards the end of this growth, China had a population of around 60 million. This was a quarter of the total world population at the time – around 2 million greater than the Roman Empire.

The magnetic compass increased trade routes

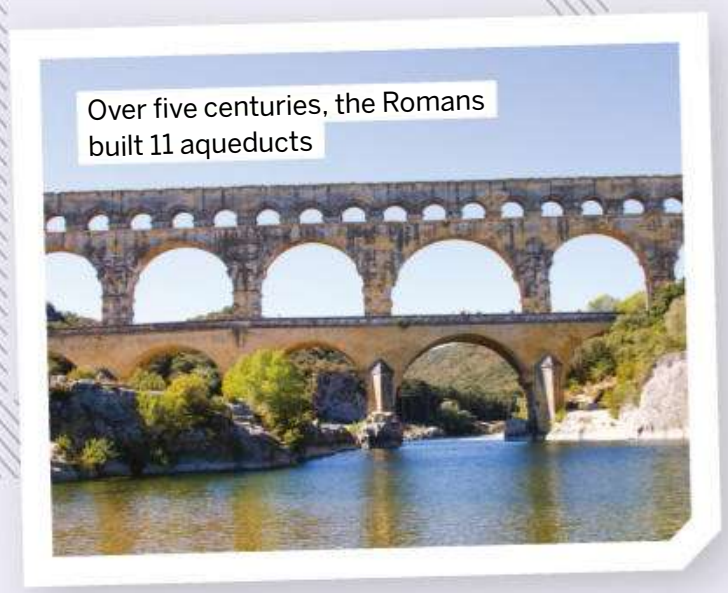
COMPASS NAVIGATION
By the 1300s, compasses were in widespread use, helping sailors travel overseas with higher accuracy. In turn, this meant shorter and more predictable voyages. Europeans used this device to explore, colonise and trade in other continents.

27 BCE to 476 CE | **206 to 220 CE** | **500 to 800 CE** | **12th century**

ROMAN RULE
The Roman Empire grew to be 1.93 million square miles in size and is estimated to have contained more than one-fifth of the world's total population. The empire grew largely by offering citizenship as a Roman to nations it conquered. However, there were other methods used by the Romans that helped the global population to grow from 150 million to around 190 million. With the growth of the empire came the expansion of the city, and new engineering was developed in order to sustain such large populations.


Khiva, in Uzbekistan, is one of the ancient cities built along the Silk Road

THE SILK ROAD CONNECTION
When the Han dynasty opened trade with the West, goods and cultural ideas could be shared along a long trade artery. Called the Silk Road, this route comprised 4,000 miles of numerous paths and diversions, extensively travelled by traders. The Silk Road was monumental in sharing technologies and information that could support growing populations.

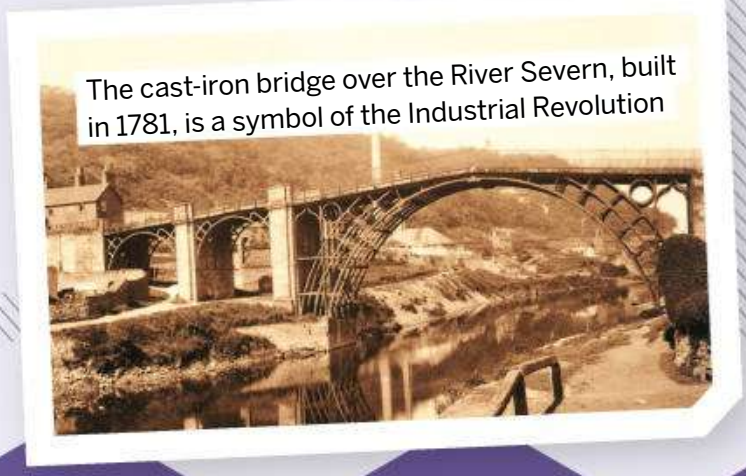

Over five centuries, the Romans built 11 aqueducts

Did you know?
50.5 per cent of the population is male

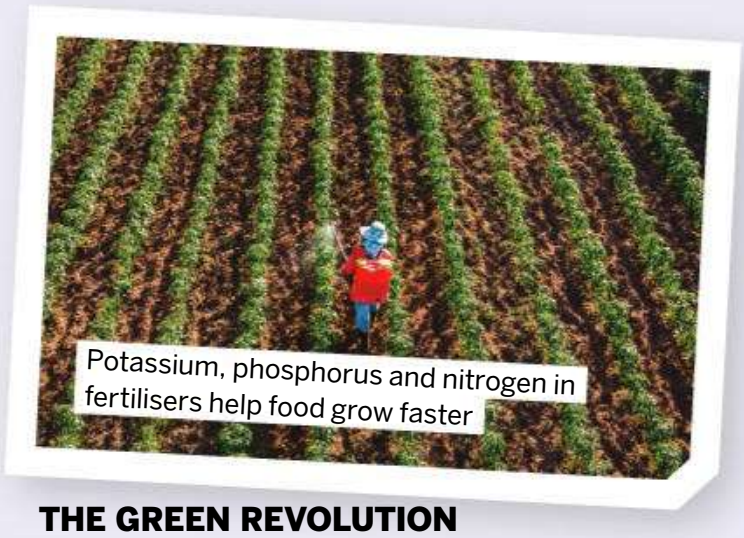
DID YOU KNOW? It took just 11 years for the world population to go from 7 to 8 billion people

THE INDUSTRIAL REVOLUTION

This period of technical innovation changed the way people lived through the invention of new machines and technology, reducing manual labour and improving the speed of production and other chores. During this period, the global population rose from around 800 million to 1.2 billion.



The cast-iron bridge over the River Severn, built in 1781, is a symbol of the Industrial Revolution



Potassium, phosphorus and nitrogen in fertilisers help food grow faster

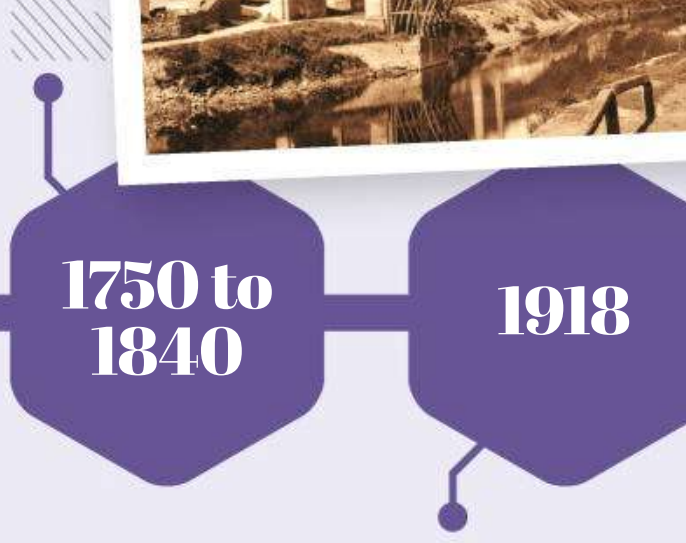
THE GREEN REVOLUTION

During this period, not only did the area of farmland increase, but so did the methods used to improve crop growth and yield. Farming practices used in Western countries were adopted by India and other Asian countries to increase available food. Before the Green Revolution, one farmer produced enough food to feed just 2.5 people. Today, each farmer can feed around 130 people.

1750 to 1840 | **1918** | **1967 to 1978** | **The future**

MODERN MEDICINE

Vaccines, antibiotics and complex medical treatments have greatly reduced the number of disease-related deaths and increased human life expectancy from 30 to 80. By more than doubling the lives of the world's population, more generations can live alongside each other than ever before. By preventing death, modern medicine inevitably has a significant and direct impact on the number of people on Earth.



2.1 per cent of the global population died during the Spanish flu pandemic

As more children are living into adulthood, the average number of children per family is decreasing

PREDICTING POPULATIONS

In 1952 the world population reached 2 billion, and it has since grown by 6 billion. According to recent predictions by the United Nations, there will be 8.5 billion people on the planet in 2030, 9.7 billion in 2050 and 10.4 billion by 2080. From the 2080s, the population is estimated to remain at around 10.4 billion until the year 2100. This is due to fertility rates falling and stabilising.

5 POPULATION-BUSTING EVENTS

1 WORLD WARS
During times of war, death rates are high and fertility rates are low. In World War II, around 50 million people died in combat, while 20 to 30 million were lost to war-related famine and disease.

2 THE BLACK DEATH
The Black Death was a bubonic plague pandemic that first emerged in the 1300s. In Europe, it took 80 years for the population to recover. Worldwide, the Black Death reduced the population from 475 million to between 350 and 375 million.

3 SMALLPOX
Since 1900, this contagious disease has claimed more than 300 million lives. Today, however, vaccination has eradicated the disease so that it no longer poses a threat.

4 GUNPOWDER INVENTION
Gunpowder was accidentally invented when scientists were experimenting with making a life-lengthening medical drink. However, the explosive chemistry of gunpowder now makes up most of the world's deadly weapons.

5 POPULATION CONTROL
Many countries have national population control laws in place that dictate how many children each family can have. In 50 years, it's helped the average number of children per family to halve from 5.0 to 2.5.

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BRAINDUMP

Amazing answers to your curious questions

Is it possible to build a time machine?

@ajmtennis

So far it's only possible to travel forward in time, and only by fractions of a second. Imagine there are two identical twins; the first travels into space in a high-speed rocket, while the other remains on Earth. When the first twin returns, they find they have aged less than their earthbound twin. This happens because of something called 'time dilation' – at high speeds, the faster something travels, the slower time passes for it. This effect is seen in global positioning system (GPS) satellites. As GPS works by precisely timing signals sent from the satellites to receivers on Earth, it's vital for the clocks involved to have nanosecond accuracy. However, the satellites are travelling fast enough that time dilation occurs on the nanosecond scale, meaning the satellites are travelling through time at a slightly different rate to the receiver on Earth. If we could develop technology to travel fast enough to take advantage of time dilation, then it could be considered to be a time machine.

Danish physicist Niels Bohr was a supporter of wave-particle duality

WHAT IS WAVE-PARTICLE DUALITY?

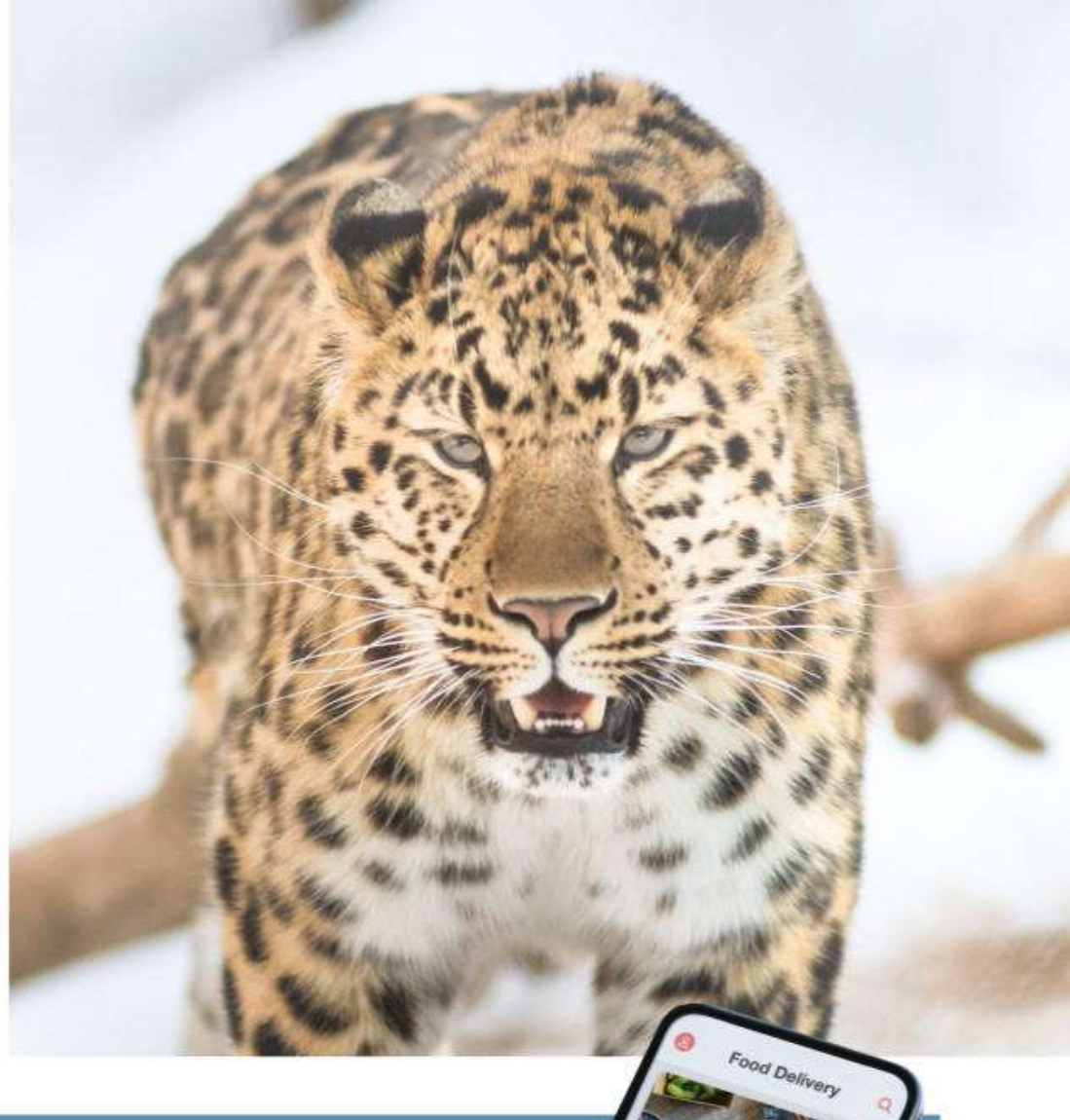
Ben Jones

Wave-particle duality is a facet of quantum mechanics that postulates that all particles exhibit both wave-like and particle-like characteristics. While seeming a paradox, this duality helps address the inability of classical physics' concepts such as 'particle' and 'wave' to accurately describe the behaviour of quantum-scale objects. Instead of isolating particles and energy as two separate categories, with only the latter exhibiting waveform characteristics, wave-particle duality removes that separation and postulates that the state of every subatomic particle can be described by something called a 'wave function' – a mathematical representation used to calculate the probability that the particle will be in a given location or state of motion. In brief, wave-particle duality indicates that elementary particles and waves show predictable properties in certain conditions, but are and can be highly unpredictable when measured on a quantum level.

WHAT'S THE RAREST BIG CAT, AND WHY?

Gavin Peterson

The rarest big cat is the Amur leopard (*Panthera pardus orientalis*). The most recent count put the population at 70 left in the wild and declining, which means they are critically endangered. They face various threats including habitat loss, poaching and climate change. The Amur leopard is a subspecies of leopard that includes the more familiar African leopard, which as a whole species is not as rare. At the species level, snow leopards (*Panthera uncia*) are rarer, with an estimated 4,500 to 7,500 remaining. You can find out more at the International Union for Conservation of Nature's Red List website, found at **iucnredlist.org**.



HOW DO SMARTPHONES ACCESS THE INTERNET?

Lucy McKenzie

The way smartphones send and receive data is different from the way they make calls in that data is sent to and from the web instead of another phone. The incoming and outgoing data is converted into tiny segments called data 'packets'. These are labelled either 'voice' or 'data' and treated accordingly. Web search data is sent as packets to the nearest base station and from there on to the internet. The reply will return by the same path and will be decoded by your phone.

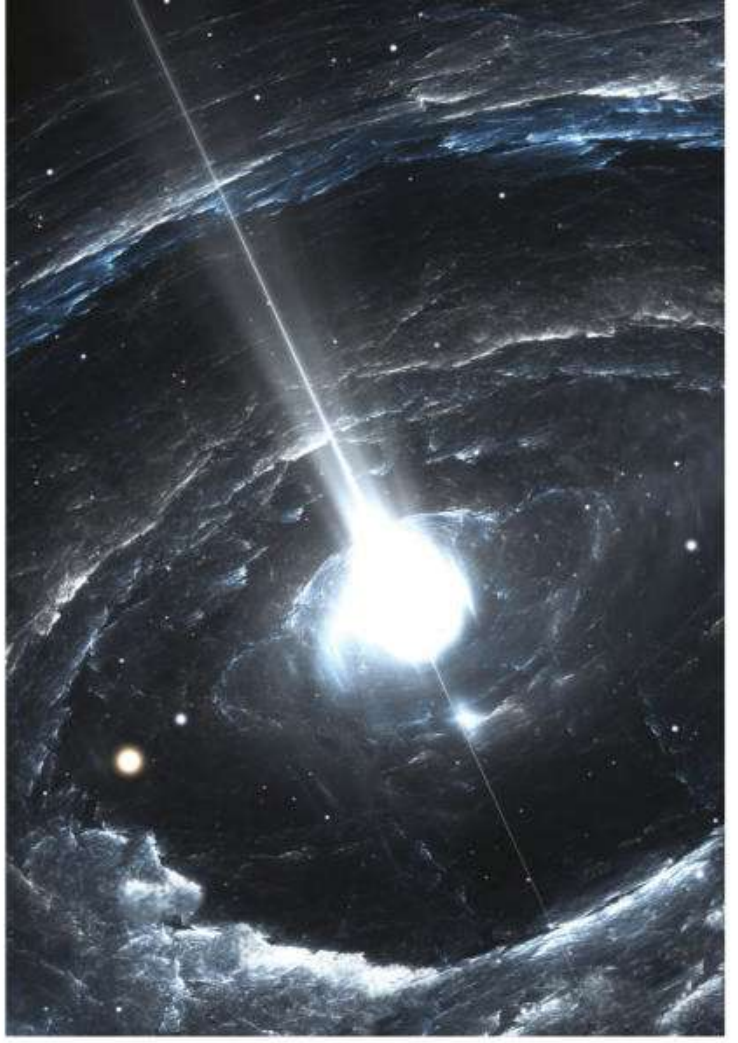
Why do pelicans have such large beaks compared to other birds?

Rebecca McTavish

It's the unique long bill with its voluminous distensible pouch that makes pelicans remarkable. The upper mandible is strong and stiff, while the lower mandible is loosely articulated and flexible to enable considerable distension of the enormous skin pouch which hangs from it. Both the large bill and the massive pouch are evidently adaptations to the bird's requirement of catching a great quantity of fish. In addition, the bill is very sensitive and can detect fish in murky water. The upper mandible acts as a lid for the pouch when it's used like a fishing net, and the pouch can hold as much as 13 litres of water after a catch.

© Alamy / Getty

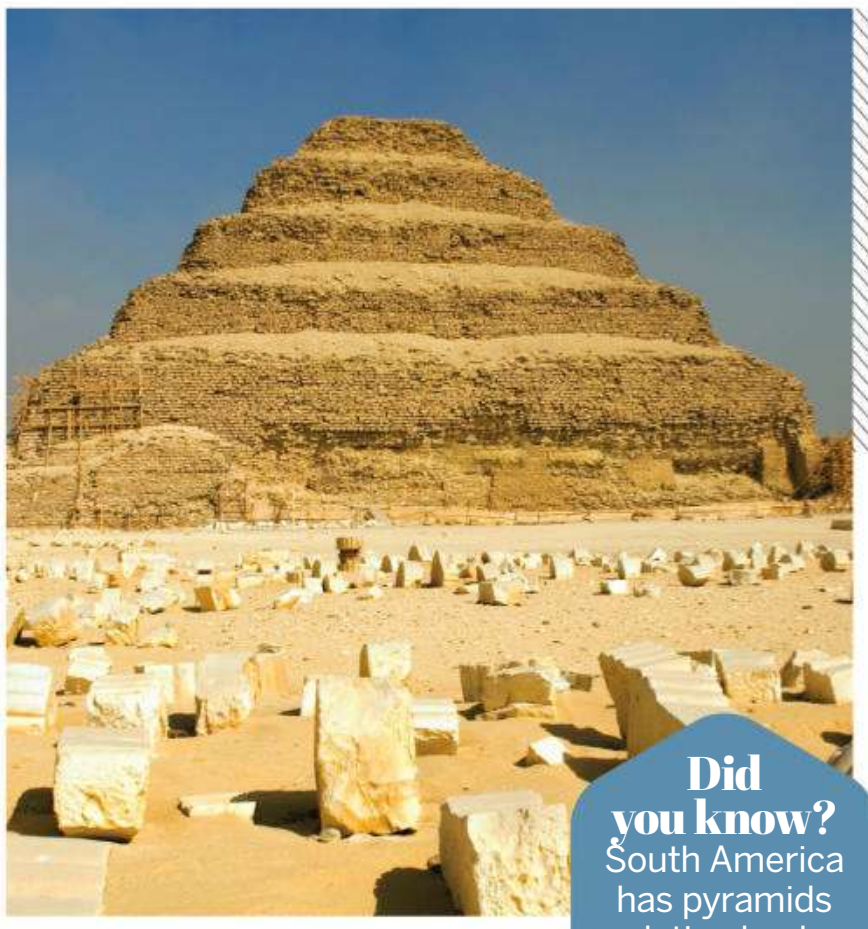
BRAINDUMP



WHAT'S THE DIFFERENCE BETWEEN A NEUTRON STAR, A WHITE DWARF AND A BROWN DWARF?

Steve Redd

A neutron star is the remnant of a supermassive star in which the nuclear reactions inside it could no longer counter the effects of its own gravity, causing it to collapse in on itself. A white dwarf is a remnant of less massive stars. They doesn't collapse in on themselves, but rather 'shed' off their outer layers after depleting their nuclear fuel. These layers are visible in the form of a planetary nebula surrounding the star. Brown dwarfs are, in essence, failed stars that never reached high enough temperatures and pressures to start nuclear fusion in their cores.



What's the oldest pyramid in Egypt? Who was it built for?

Chris Sanders

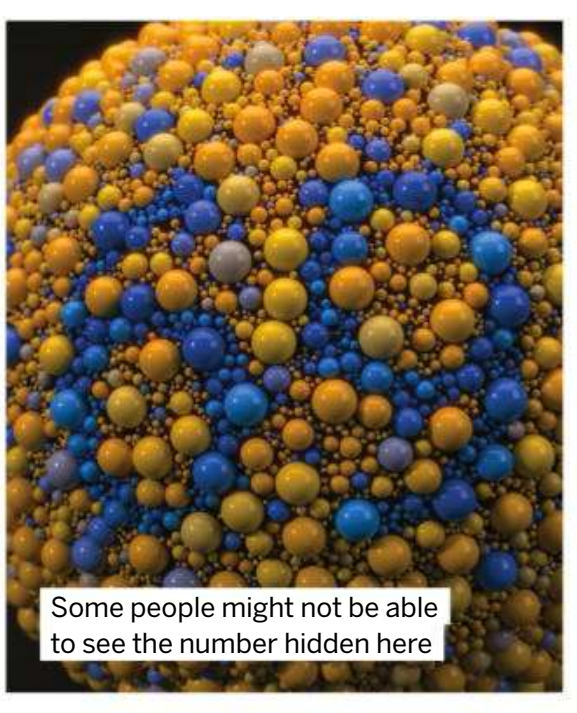
The step pyramid at Saqqara is the oldest pyramid. It dates to the reign of King Djoser, who reigned from around 2667 to 2648 BCE during Egypt's Third Dynasty. The step pyramid is the first building in Egypt to be constructed out of stone. The pyramid itself began as a 'mastaba' tomb, a long, low rectangular tomb. The architect then added levels until the building took on the form of a stepped pyramid. The pyramid is located within a large walled compound, believed to be a copy of the palace of the king.

Did you know?
South America has pyramids dating back millennia

WHAT IS THE CAUSE OF COLOUR BLINDNESS?

@macdonut

There are many different types of colour blindness, either caused by hereditary genetic deficiencies or retinal diseases or damage. All types stem from problems in the sufferer's retina, the light-sensitive layer of tissue within the eyeball. Here, there are three types of cones – the retina's visual cells that deal with the perception of colour – each absorbing differing light wavelengths. For example, one type of cone absorbs longer wavelengths (red), while others specialise in shorter ones (blue and green). If one or multiple of these cell areas are incompletely developed or damaged, then various degrees of colour blindness can ensue. The most common type of colour blindness is protanopia, which is the inability for a person to clearly differentiate between red and green.



Some people might not be able to see the number hidden here

WHAT'S THE DIFFERENCE BETWEEN DNA AND RNA?

Michelle Williams

With the exception of some viruses, all organisms originally store their genetic information as DNA (deoxyribonucleic acid) before making RNA (ribonucleic acid) through a process called 'transcription'. RNA is then used to make proteins by a process called 'translation'.

Chemically, DNA and RNA both consist of nucleotides linked together. A nucleotide comprises a ribose sugar,a phosphate group and a nitrogenous base. The ribose sugar in DNA is different to that of RNA because it is missing a hydroxyl group, -OH – one oxygen joined to a hydrogen atom. This missing hydroxyl group from DNA makes it less reactive than RNA, making DNA a more stable carrier of genetic information.

Both have bases called adenine, cytosine and guanine. However, DNA has a fourth base called thymine while RNA has a fourth base called uracil, similar to thymine but lacking a methyl group, $-CH_3$ – one carbon atom joined to three hydrogen atoms.

How does a SEM work?

Charles Rodway

A scanning electron microscope (SEM) uses high-energy electrons to scan a specimen's surface, creating a 3D image. In a conventional SEM, the specimen is placed in a vacuum. An electron beam passes through a couple of condenser lenses, which apply a magnetic field to narrow the beam and apertures (holes) to block stray electrons. The beam causes some electrons to be ejected, which can then be detected and amplified to produce an image of the sample surface.

Microscopes can uncover tiny details in the world around us

© Getty

Could we colonise Mars?

Nicky Yao

There are many things that make Mars one of the most likely planets for colonisation within our Solar System. The Martian day is just under 40 minutes longer than an Earth day, Mars has a thin atmosphere that provides some protection from solar radiation and proof of sizeable quantities of elements necessary to support life has been found on Mars. Although terraforming Mars – changing it to be more like Earth – is theoretically possible, it is well beyond our current technology and would be crippling to the economy. The biggest problems faced in trying to colonise Mars are with the vast differences in pressure, gravity and atmosphere. Settlers would have to wear pressure suits that protect against radiation from the Sun. Flights from Earth could take six to nine months with current technology.

WHAT'S THE DIFFERENCE BETWEEN WEATHER AND CLIMATE CHANGE?

David Black

Weather is temperature, precipitation – rain, hail, sleet and snow – and wind, which change hour by hour and day by day. Climate is the general long-term character of the weather and the nature of its variations that we experience over time. Earth's climate has changed on many timescales in response to natural factors. Over thousands of years we see Earth move in and out of ice ages. At the other extreme, El Niño, variations in surface temperature of ocean water across the tropical eastern Pacific Ocean, come and go every few years, temporarily raising Earth's temperature. Over the course of the last century there has been an unusual increase in the average global temperature, accompanied by changes in extremes of weather. The term 'climate change' is used to refer to changes to our climate arising from human activities.

Did you know?
The weather has an influence on migration patterns

Michael Faraday coined the term 'electrode'

WHAT IS AN ELECTRODE?

Gavin Oldfield

An electrode conducts electricity in an electric circuit. It can come in the form of a plate, rod or wire and is usually made of metals like copper, lead, zinc or silver. Most metals in a circuit conduct electricity. The role of electrodes is different as they let electric current flow to parts of the circuit that are not made of well-conducting metal. Some electrodes are made of non-metallic substances like carbon. Electrodes used in batteries are either anodes or cathodes, depending on the electric charge.

WHY DO 3D MOVIES LOOK WASHED OUT?

Kelly Banks

Modern 3D cinema uses a system of polarised light. Light travels in waves that oscillate in different directions and angles. Films in 3D use two projectors which are each passed through polarising filters that only allow for light travelling in one direction. One projector has a filter that only lets vertical waves of light through, and the other only lets horizontal waves of light through. The naked eye sees light waves in all directions, so without the 3D glasses you can see the output of both projectors as two images at once. Seeing light waves in just two directions cuts down the amount of light that the eye sees, which means that the film looks dimmer than conventional 2D films without glasses.

What is the source of the River Nile?

Gemma Craven

One of the world's longest rivers, the Nile stretches a colossal 4,132 miles and passes through nine whole countries. Its origin, while contested, is generally accepted to be in Lake Victoria, which borders the African countries of Tanzania, Kenya and Uganda. Starting at the northern edge of the lake, water pours over a waterfall known as the Ripon Falls and into a narrow opening. It is here that the White Nile begins – one of the Nile's two main tributaries. It later meets with the Blue Nile, which originates in Lake Tana, Ethiopia.

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The latest book releases for curious minds

AMAZING ANIMAL JOURNEYS

DISCOVER EPIC ADVENTURES IN THE ANIMAL KINGDOM

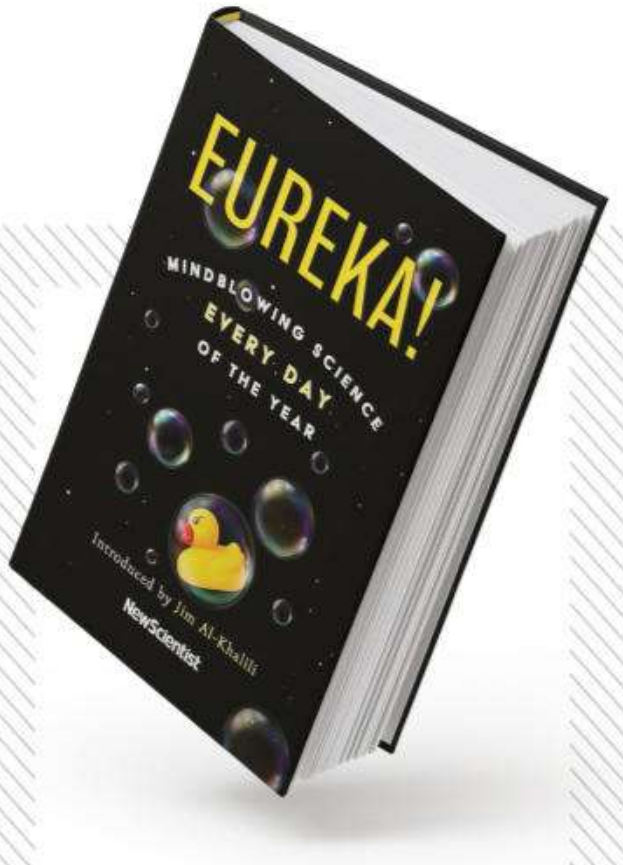
AUTHOR **PHILIPPA FORRESTER**
PUBLISHER **DORLING KINDERSLEY**
PRICE **£20 / $24.99**
RELEASE **2 FEBRUARY**

If the author's name rings a bell, it's because Philippa Forrester is best known for being a TV presenter, on the likes of popular future technology programme *Tomorrow's World* and the fantasy demolition derby that is *Robot Wars*. Although, she's also a natural history expert with several wildlife books to her name. In pursuit of a career beyond broadcasting, in recent years she moved from the UK to Wyoming, the US state that's home to a national park internationally renowned for its breathtaking natural beauty. And many of the animals in her latest book also feature similar migrations to hers – thousands of miles long across a range of natural and urban environments.

Amazing Animal Journeys compiles species from across the breadth of the animal kingdom, showcasing the incredible voyages that they make: whether that's to escape bitter winters to warmer climates, or in the case of the sloth, a short trip to the toilet at the bottom of their tree that nevertheless takes them an entire week and is fraught with danger. Any wildlife buff will be familiar with the migratory voyages of some of the bird species, the Arctic tern, swallow or the bar-tailed godwit, for example - the latter of which recently broke the world record for longest documented non-stop flight by any animal when a juvenile godwit flew 11 days straight to migrate 8,425 miles from Alaska to Tasmania, Australia. But there are plenty of surprises for everyone in *Amazing Animal Journeys*, like the railway journeys of the Italian wall lizard, the unbelievable depths that Cuvier's beaked whales will dive to in search of food and the mind-boggling micro adventures of the tiny tardigrade, whose resilience will put any other species on the planet in the shade.

"It compiles species from across the breadth of the animal kingdom"

Each animal gets a fact-packed write-up, an easy read that will engage anyone from school-age upwards, plus a generous amount of imagery to illustrate their individual journey in the form of diagrams, cutaways and high-resolution photos that publisher DK has made its name with. *Amazing Animal Journeys* would look at home on a coffee table just as much as it would on a bookshelf at home or in a school library.



EUREKA!

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AUTHOR **NEW SCIENTIST**
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Every entry is snappy and easy to understand, making it the perfect book to dip into on your lunch break, while the kettle is boiling or with any spare minutes you have in the day. As the seasons change, you'll notice the themes of the questions match the time of year, providing topical knowledge you can share with friends. By the end of the 365 days, your brain is sure to be filled with a combination of fun hypothetical questions and answers, as well as facts that will better shape your understanding of the fascinating world we live in.

BIRD DETECTIVES

SCIENCE SLEUTHS AND THEIR FEATHERED FRIENDS

AUTHOR **KRISTINE RIVERS**
PUBLISHER **CAPSTONE PRESS**
PRICE **£7.99 / $8.99**
RELEASE **OUT NOW**

The study of birds has been of major importance to humans throughout history. At sea, sailors once used birds as their guide to find land, while the aeroplanes people now use to travel between continents were originally designed to imitate the way birds fly. Unfortunately, with both birds and humans flying, the sky is a much busier place. Occasionally, planes' and birds' paths cross, putting birds' lives in danger and damaging aircraft.

This book is all about ornithologists, otherwise known as 'bird detectives'. Aimed at children between the ages of 8 and 12, *Bird Detectives* explains how a career in ornithology involves investigating bird species from small samples of DNA. This increases the knowledge of where different birds are found, how specific accidents were caused and ultimately how to prevent these collisions from recurring.

As you progress through the book, learning about how feathers, footprints, blood and other clues are analysed to identify birds, you can also open your own case. Dispersed throughout the pages are interactive clues that point to a mystery bird. See if you can correctly name it before the correct answer is revealed towards the end.

Whether young readers are simply interested in the scientific procedures involved in ornithology or they want to become an airfield biologist who monitors and protects birds in the busiest areas above land, *Bird Detectives* offers guidance for how to make this choice of career path.

WORLD OF WEIRD

A CREEPY COMPENDIUM OF TRUE STORIES

AUTHOR **TOM ADAMS**
ILLUSTRATOR **CELSIUS PICTOR**
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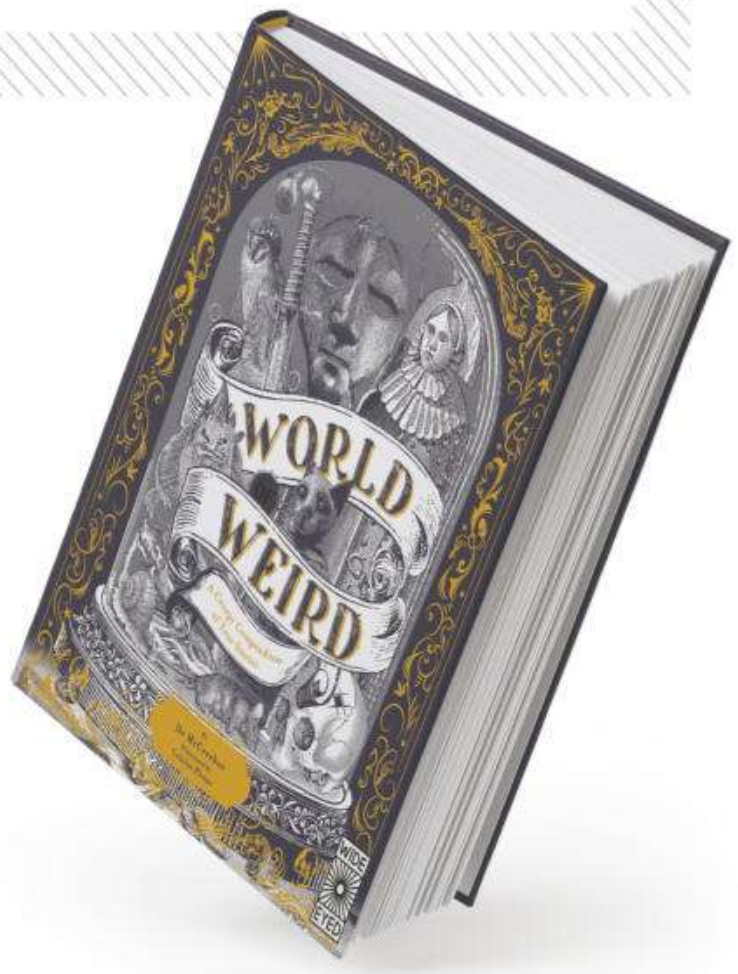
Delve into the world of the fascinating stories behind some of history's weirdest objects. Written in the style of a Victorian notebook, each chapter focuses on different dark and disturbing inventions, items and stories that fictitious explorer, philosopher and collector Dr McCreebor has collected over the years. From historical artefacts and human-made oddities to strange occurrences in nature and from beyond the grave, this book is packed with some of the weirdest and spookiest stories from throughout history.

The macabre trivia is accompanied by wonderfully haunting illustrations, maps and footnotes that create a truly eerie mood in each chapter. This brilliant book is full of factual information packed into a fictional frame, perfect for slightly older children who want to discover humankind's seriously strange past. Although the contents are geared towards the grisly side of history, it's not overly graphic.



THE MOST IMPORTANT ANIMAL OF ALL

MEET THE CREATURES THAT KEEP THE WORLD TICKING OVER

AUTHOR **PENNY WORMS**
ILLUSTRATOR **HANNAH BAILEY**
PUBLISHER **MAMA MAKES BOOKS**
PRICE **£12.99 / $19.99**
RELEASE **OUT NOW**

From the importance of pollination to the elephant architects that build community watering holes, discover the vital roles that animals play in their environments. The vibrant imagery will quickly transport your young ones around the world to meet a whole host of animals, including tigers, bats, orangutans and sharks. Along with beautiful illustrations, the author has used some stunning photography to annotate the anatomy of creatures, such as bat wings, beaver teeth and shrimp legs.

The book also introduces some important topics to children, such as the role of a keystone species and how they hold an ecosystem together. The book is an excellent example of how to engage a young audience with wildlife and help them see the importance of the natural world. There's also an excellent 'find out more' section at the end of the book that directs children to organisations and charities working to protect important animals.

BRAIN GYM

Give your brain a puzzle workout

Sudoku

Complete the grid so that each row, column and 3x3 box contains the numbers 1 to 9

EASY

4	2		8		9			7
5	3				7			1
9					3			
				3	6	8	9	
8	6	4	1		5	7	2	3
2	9				8		1	
		7	9		1			2
3	4		7	5	2	1		6
	8	2						

MEDIUM

		4		6				
					1	7		8
1				3			4	
			1	8	3	4	5	
		8			5	9	6	
4	2				7	1		
6		3		7				1
5	4		3		6			
		1	2		8			4

HARD

3		8			1		7	
	7			5		4	1	
				6				
	6							
	9							4
		4			2	7	8	
7	2					9	4	5
		5	7					6
1					3			

Word search

Find the following words

GUM
SCORPION
HUMANS
BALLOON
ELECTRIC
JET
OLYMPUS
CANNIBAL
ROBOT
TYRE
TOBACCO
FEET

J	E	B	C	A	N	N	I	B	A	L	A	P	O	B
G	U	M	G	U	N	O	N	R	O	C	F	E	E	A
I	T	O	P	W	H	T	Y	R	E	G	A	C	C	L
B	O	O	N	A	L	E	E	T	L	Y	X	C	R	L
J	B	E	S	L	H	U	M	A	E	N	O	I	Y	O
G	A	R	C	C	A	M	N	I	B	E	U	R	L	O
F	C	E	O	L	Y	M	P	U	S	E	F	T	X	N
K	C	B	R	F	J	A	E	T	Z	V	I	C	M	P
S	O	C	P	O	R	P	I	O	N	E	F	E	T	Y
R	E	L	I	O	L	Y	N	C	U	S	H	L	J	E
T	C	R	O	B	O	T	A	N	N	I	B	E	D	O
J	A	R	N	B	G	S	H	A	F	E	F	T	C	Y
E	Y	N	T	S	M	A	M	U	H	Y	Z	I	E	M
T	O	B	A	C	K	U	B	A	O	O	L	L	N	C
N	I	G	H	B	H	A	X	E	K	P	I	E	J	A

What is it?

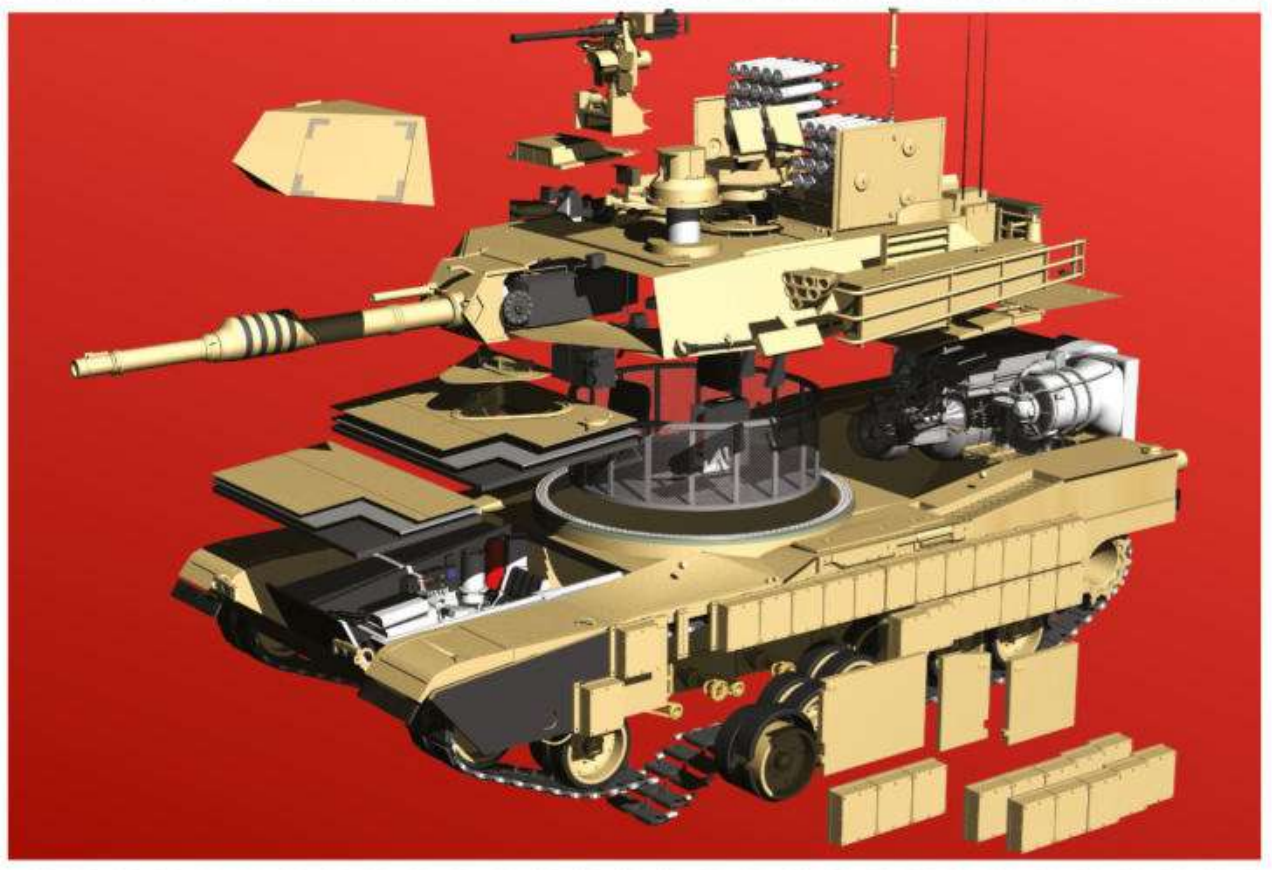
Hint:

A feline view of the road

A

Spot the difference

See if you can find all six changes between the images below



Answers

Find the solutions to last issue's puzzle pages

Q1 EXTRACT TEETH
Q2 MEDIEVAL WEAPON
Q3 IT EXPANDS
Q4 80 WATTS
Q5 95 PER CENT
Q6 CAN'T SEE IT

What is it?

ORCHID MANTIS

Spot the difference

QUICKFIRE QUESTIONS

Q1 The oldest artificial Christmas tree that's still in use was made in...

- 1886
- 1926
- 1956
- 2006

Q2 How many muscles are in an elephant's trunk?

- 40
- 400
- 4,000
- 40,000

Q3 How do International Space Station astronauts do their laundry?

- A space laundrette
- It's sent to Earth
- It burns on re-entry
- ISS washing machine

Q4 What is the chemical symbol for gold?

- Go
- Ag
- Au
- Hg

Q5 What colours can dogs see?

- Green and red
- Red and yellow
- Yellow and blue
- Blue and pink

Q6 What year was bubble wrap invented?

- 1857
- 1907
- 1957
- 2007

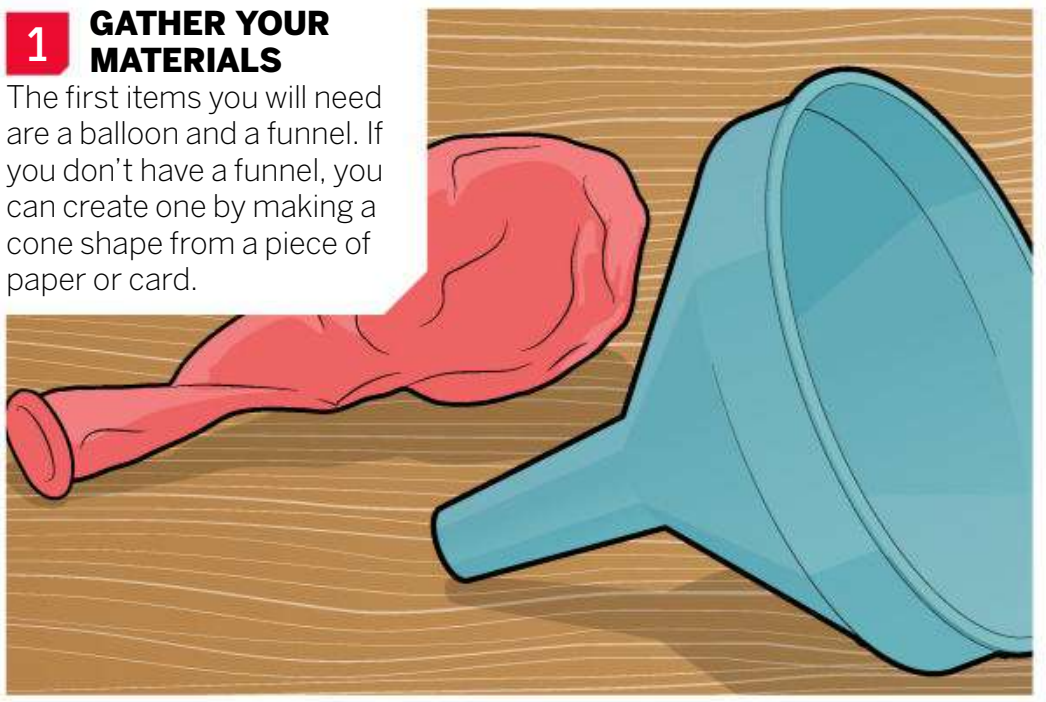
© Getty

HOW TO...

Practical projects to try at home

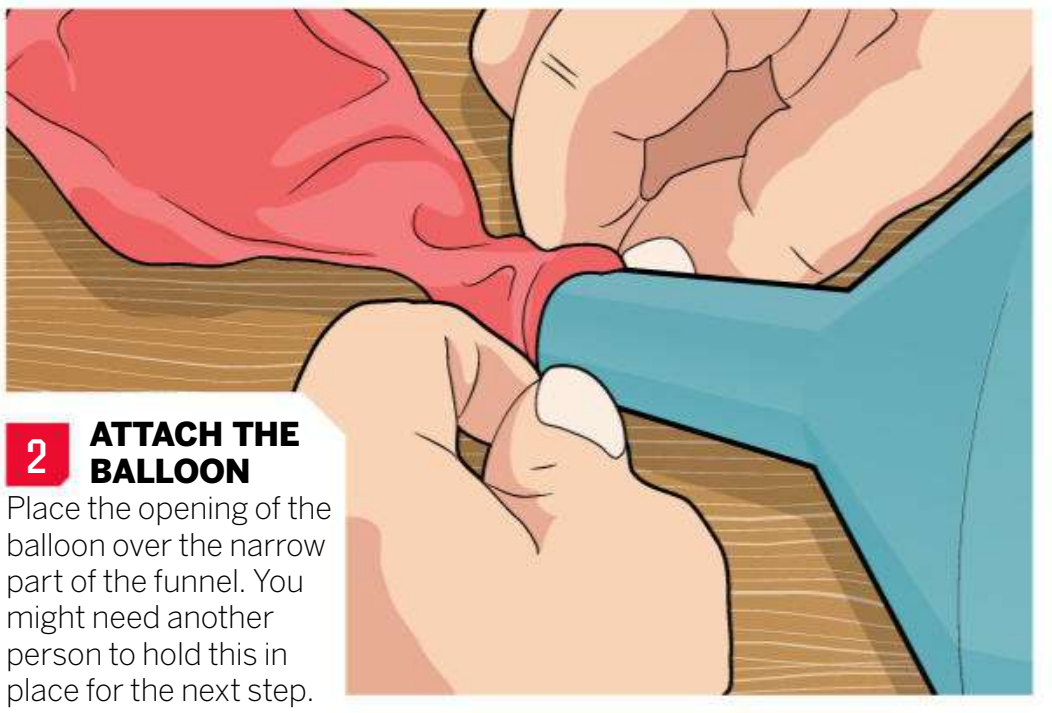
MAKE A SELF-INFLATING BALLOON

Watch a balloon expand thanks to these two reactive kitchen ingredients



1 GATHER YOUR MATERIALS

The first items you will need are a balloon and a funnel. If you don't have a funnel, you can create one by making a cone shape from a piece of paper or card.



2 ATTACH THE BALLOON

Place the opening of the balloon over the narrow part of the funnel. You might need another person to hold this in place for the next step.

3 FILL THE BALLOON

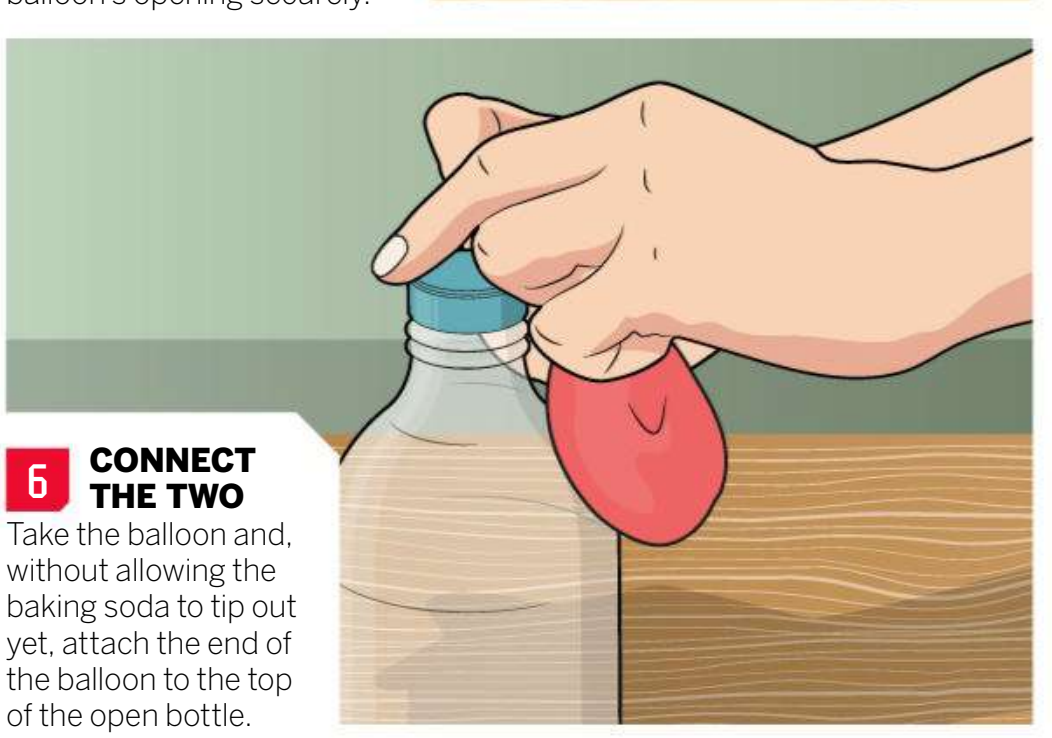
Pour the baking soda into the funnel. The funnel will direct the powder neatly into the balloon. Then place the balloon gently to one side.

4 FIND A BOTTLE

You'll need to find a bottle that will house the chemical reaction. Make sure that the top of the bottle is narrow enough to fit over the balloon's opening securely.

5 ADD THE FIRST INGREDIENT

Clean the funnel so that the chemical reaction doesn't take place prematurely, then use it to pour the vinegar into the empty bottle.



6 CONNECT THE TWO

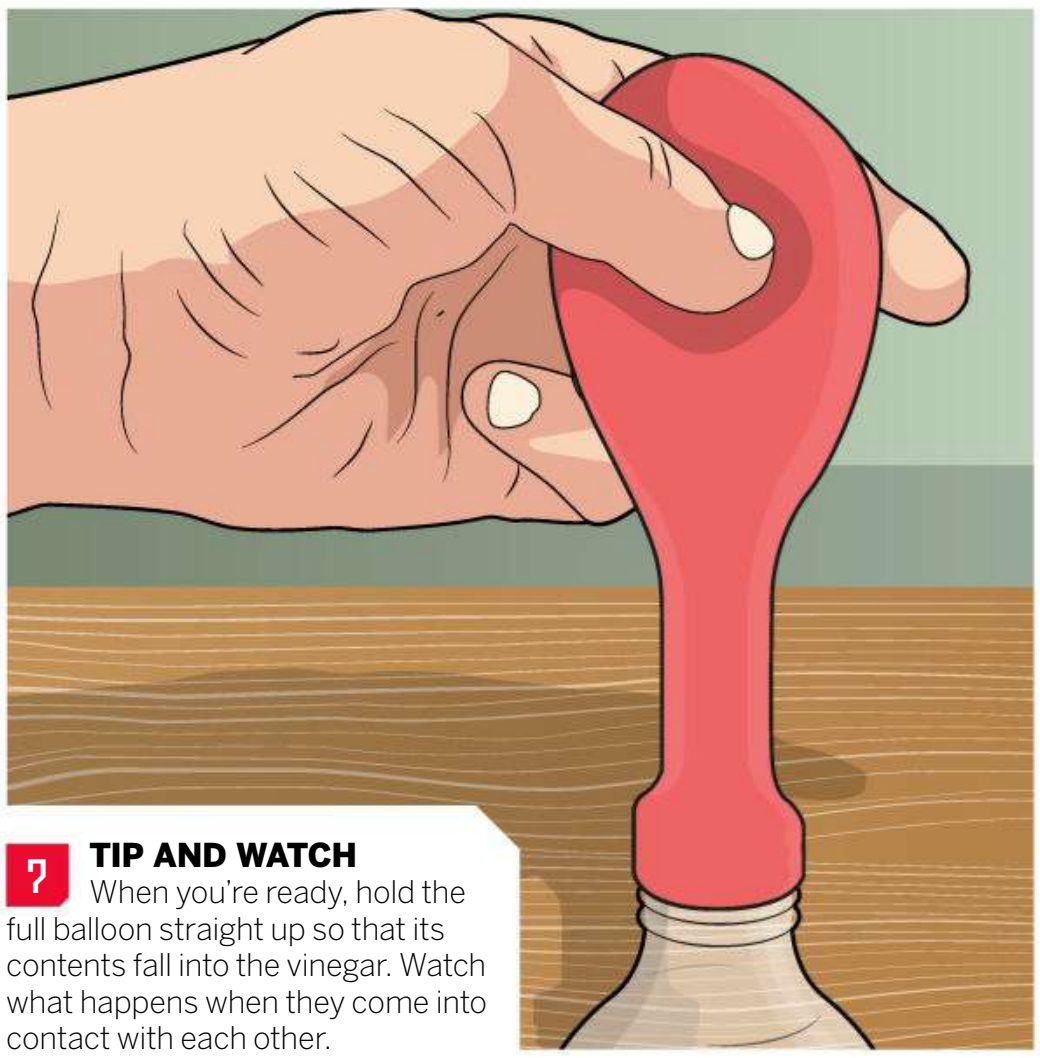
Take the balloon and, without allowing the baking soda to tip out yet, attach the end of the balloon to the top of the open bottle.

KIT LIST

- Balloon
- Funnel
- Water bottle
- Half a cup baking soda
- One cup vinegar

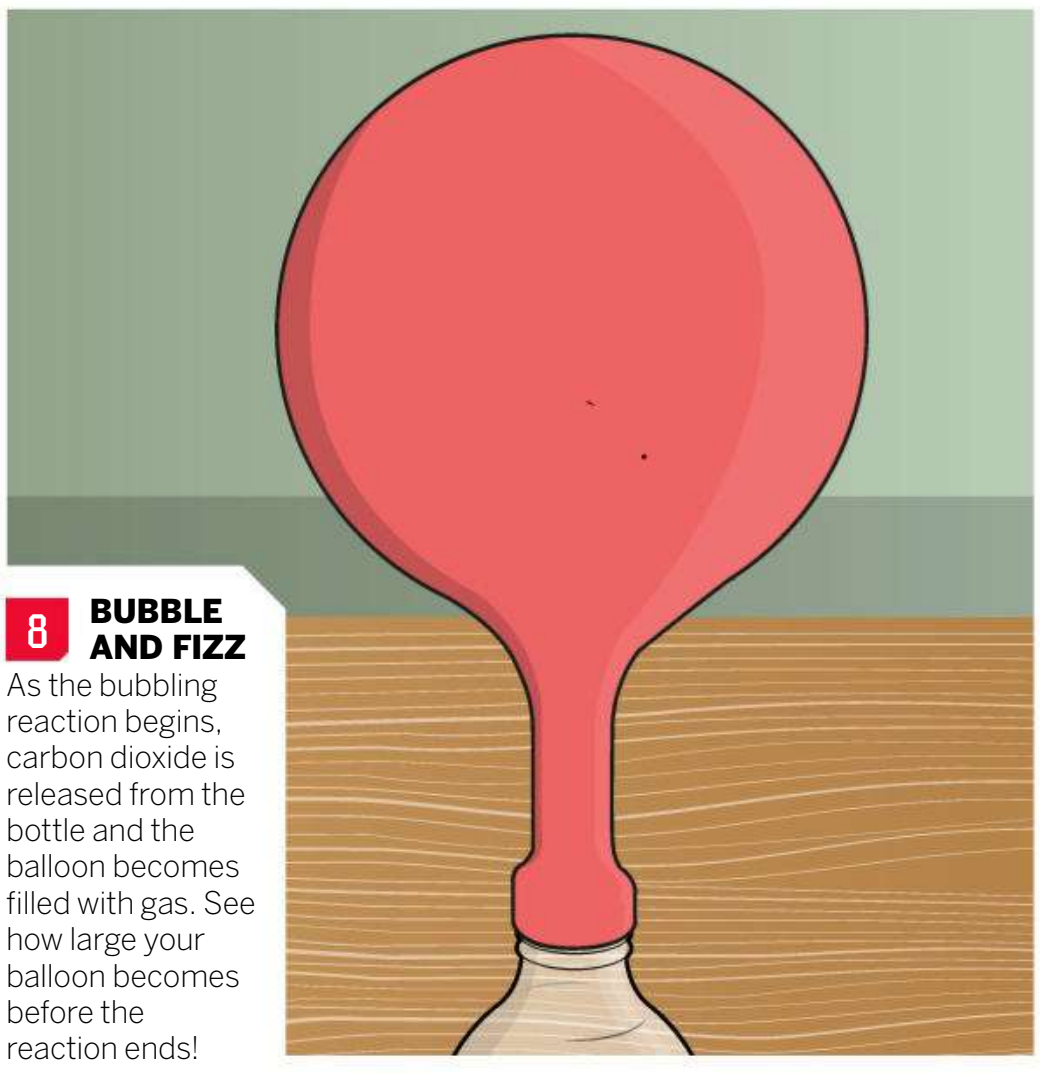
DON'T DO IT ALONE!

If you're under 16, make sure you have an adult with you



7 TIP AND WATCH

When you're ready, hold the full balloon straight up so that its contents fall into the vinegar. Watch what happens when they come into contact with each other.



8 BUBBLE AND FIZZ

As the bubbling reaction begins, carbon dioxide is released from the bottle and the balloon becomes filled with gas. See how large your balloon becomes before the reaction ends!

SUMMARY

The reaction between the baking soda and vinegar is called an acid-base reaction. Because the vinegar is an acid and the baking soda (sodium bicarbonate) is a base, the hydrogen ions in the vinegar react with the sodium ions and bicarbonate ions. As a result, two new chemicals – carbonic acid and sodium acetate – are formed. But how does this inflate the balloon? The carbonic acid is unstable, and decomposes to make carbon dioxide and water. Carbon dioxide is the gas that you can see bubbling and foaming in the bottle before it rises to fill the balloon. This gas is heavier than the surrounding air, so if you tie up the balloon and let it go, you will notice that it will fall down to the ground quite quickly. If you've tried this experiment, you can take a picture of how much your balloon inflated and email it to howitworks@futurenet.com for a chance to be featured in the magazine.

Had a go? Let us know!

If you've tried out any of our experiments – or conducted some of your own – let us know! Share your photos or videos with us on social media.

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INBOX

Speak your mind

LETTER of the MONTH

Spices and fruits are added to mulled wine in a large pan

WIN!

AN AMAZING PRIZE FOR LETTER OF THE MONTH

AMAZING ANIMAL JOURNEYS

This beautiful book allows children to discover the wondrous journeys that animals make every day, no matter how big or small

MULLING IT OVER

Dear **HIW**,
Does mulled wine actually have alcohol in it? I like the taste of it, but to me it tastes similar to juice. Is this because the heat burns all the alcohol off?
Annabel Cushin

When cooking with wine, boiling it will cause most of the alcohol to evaporate. Around 85 per cent of alcohol can be removed from a beverage when boiled. However, when preparing mulled wine, the aim is not to leave the wine boiling. The drink is brought to a simmer and is then left on a low heat. Some of the alcohol may evaporate during the mulled wine-making process, but the majority of it will remain, so don't treat it as a soft drink!

The reason you may think it tastes like juice is due to the added ingredients that give the wine a sweet and spiced flavour. Sugar, cinnamon, cloves, oranges and lemon zest are just some of the ingredients that are commonly added. When you make mulled wine at home, you have more control over how strong you make it. You can prepare the drink on a low heat to be ready for when you wish to consume it. At public events such as Christmas markets, some of the wine may have been heated in its container for a few hours. This means that more of the alcohol is likely to have evaporated. However, it will usually still have a potent alcohol content. Mulled wine is often served from a large container with a lid covering it. This is to reduce how much alcohol is lost. Some people like to add another alcoholic drink such as brandy or port to the concoction to boost the alcohol content further.

WEEING IN WINTER

Dear **HIW**,
I have a question that has been bugging me. Why is it that whenever I get really cold I need to have a wee?
Chris Lucas

This is something that happens to most people as the seasons change. And there are a few factors that can cause this to happen. Firstly, in the summer people tend to sweat more to keep cool in warm temperatures, so the body has less water to release as a waste product during these months. Another reason that you may find yourself visiting the toilet more frequently in winter is that more blood is directed to your internal organs than towards your skin. This is to prevent heat being lost into the surrounding air. Your kidneys, which function to filter blood and release waste products, have more work to do when higher volumes of blood are pumped to them. With more blood to process comes more waste products, meaning more urine is produced. Finally, hypothermia is another more serious possible cause. It's important to try and keep yourself warm throughout the winter rather than relying on your body's biology alone to tackle the elements.

It's natural to feel the need to go to the toilet more frequently if you're cold when cold is natural

QUESTIONS ABOUT CANDLES

Dear **HIW**,
What's a candle wick made from? As the wax gets lower, does this mean lighting a candle fills the air with wax?
Marc Rahman

The wick delivers wax fuel to the flame, so it needs the right materials to burn, usually braided or plaited cotton fibres. Against the force of gravity, the wax moves up the wick into tight spaces. This process is called wicking. The tighter the fibres are braided, the slower the fuel will move and the longer burning the candle will be. Most of a candle is released into the air. Wax is made up of hydrogen and carbon; as it burns it's released mostly as carbon dioxide and water vapour.

Wicks draw the candle's fuel towards the flame

NEXT ISSUE

ISSUE 174

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Spider monkeys can hang from trees using their tails alone

TAIL TALENTS

Dear **HIW**,
I love monkeys. I think they're the most interesting animals to watch how they move, especially when they climb with their tails. How else do monkeys use their tails?
Roya Raza

The tail is a great fifth limb, which monkeys mostly use to better navigate trees. Holding onto branches with their tails helps them keep their hands free to look for food and carry items. Old-world monkeys, which inhabit Africa and Asia, use their tails as a tool for balancing, while new-world monkeys – those in Central and South America – have longer tails that they can wrap around branches for climbing. Spider monkeys have the most dextrous tails, which they also use to catch objects and communicate by making signals at other monkeys.

Babies and young children are more prone to falling out of bed while asleep

PEACEFUL SLEEPING

Dear **HIW**,
Why don't I fall out of bed at night when sleeping? Does this happen to people anyway?
Stephen

When you are asleep you use a sense called proprioception to monitor your position in bed and keep you safe. This sense means that your body knows when and how you are moving, even when you are unconscious. As you reach the deepest stage of sleep, your brain signals the body to stop moving. Without this, you're more likely to react to dreams and end up on the floor. Babies need a cot to stop them from falling out of bed as the ability to use proprioception is less advanced when we are young.

WE ASKED YOU

This month on social media, we asked you: If you could adopt one animal ability, what would it be?

@FATEMEH.JINYOUNG
Whales' ability to hold their breath for so long so I can explore the oceans

@CEETJE.MOUTON
Night vision

@LOUISTYNDALL
Octopus – they can regrow their limbs and camouflage

@JEANMCDOUGALL8333
Swim underwater

@DOODLENEWS_
I would like echolocation so that I can navigate even with my eyes closed. This would be useful if I need to go to the toilet in the middle of the night

@AETHETICALLY_AJ
To be able to walk up walls and on ceilings like geckos

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HOW IT WORKS

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Printed by William Gibbons & Sons Limited
26 Planetary Road, Willenhall, Wolverhampton, West Midlands, WV13 3XB

Distributed by Marketforce, 5 Churchill Place, Canary Wharf, London, E14 5HU
www.marketforce.co.uk
Tel: 0203 787 9001

ISSN 2041-7322

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FAST FACTS

Amazing trivia that will blow your mind

50 BILLION

The estimated number of galaxies in the known universe

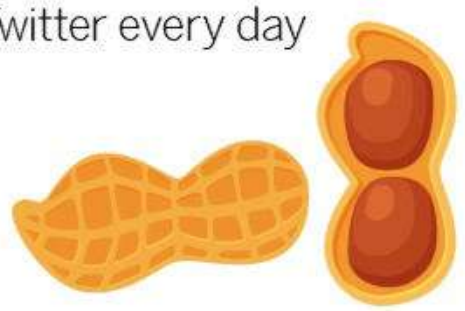
PHONE MANUFACTURER NOKIA USED TO SELL TOILET PAPER

500 MILLION

Half a billion tweets are tweeted on Twitter every day

7.7 billion

MOBILE PHONE OWNERS OUTNUMBER THOSE WHO HAVE A WORKING TOILET BY NEARLY 2:1



1890

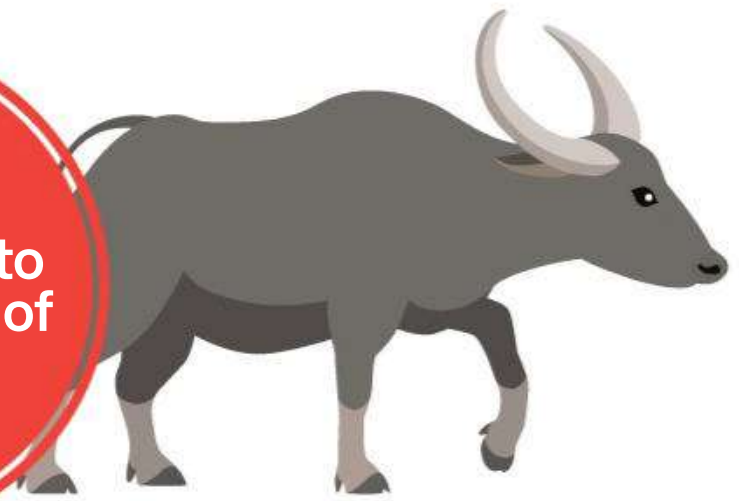
The world's first biofuel, peanut oil, was invented by Rudolf Diesel

40%

Nearly half of the world's freight is transported by train

$9,100

It costs a lot to send a bottle of water into space



635 kilograms

Jon Brower Minnoch, the heaviest recorded person, once weighed as much as a water buffalo

THE MOON ISN'T ROUND – IT'S MORE LEMON-SHAPED

It's possible for water to boil and freeze at the same time

1,043 MILES

The Great Barrier Reef is the largest living structure on Earth

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